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Development of a consumable inventory management strategy for the supply management unit

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Development of a Consumable Inventory Management Strategy for the Supply Management Unit

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December 2007

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DEVELOPMENT OF A CONSUMABLE INVENTORY MANAGEMENT STRATEGY FOR THE SUPPLY MANAGEMENT UNIT

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Submitted in partial fulfillment of the requirements for the degree of

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DEVELOPMENT OF A CONSUMABLE INVENTORY MANAGEMENT STRATEGY FOR THE SUPPLY MANAGEMENT UNIT

ABSTRACT

The goal of this project is to develop a consumable inventory management strategy for the Supply Management Unit (SMU) that will be applicable to other Department of Defense (DoD) supply support organizations. The SMU is a Marine Corps wholesale activity that provides Class IX (consumable repair part) supply support to 160 Marine Corps' units. The SMU uses the Days of Supply model to establish Requisitioning Objectives (RO) and Reorder Points (ROP), which are based upon historical usage, lead time, and supply data. Historical data is generated from Class I Natural Programs that were designed in the early 1970s. Since then, inventory management has evolved from warehouses packed with supplies to warehouses carrying just enough inventories to satisfy customer demand. The evolution of inventory management has proven that there is a direct relationship between inventory and cost in that the ability to efficiently manage inventory serves as a catalyst for reducing cost. Efficient inventory management involves the ability to forecast demand accurately, establish inventory levels prudently, and provide optimal support to the customer cost-effectively. Therefore, this project will focus on developing an inventory management strategy that efficiently balances readiness with supply chain system-wide costs.

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TABLE OF CONTENTS

I. INTRODUCTION....1
A. BACKGROUND....1
B. OBJECTIVE....3
C. METHODOLOGY....4

II. FORECASTING DEMAND....5
A. PROBLEM STATEMENT....5
B. INFORMED FOUNDATION....6
1. Forecasting Methods....6
a. Moving Average....6
b. Weighted Moving Average....8
c. Exponential Smoothing....9
d. Exponential Smoothing with Trend....11
2. Basic Guidelines....12
a. First Guideline....12
b. Second Guideline....13
c. Third Guideline....13
3. Four Components of a Demand Forecast....14
4. Measurements of Forecast Error....15
5. The Bullwhip Effect....15
6. Expert Opinion Forecasting....16
C. DATA COLLECTION AND ANALYSIS....17
1. Data Collection....17
2. Data Analysis....18
a. Moving Average....18
b. Weighted Moving Average....19
c. Exponential Smoothing....19
d. Exponential Smoothing with Trend....20
3. Summary....20
D. CONCLUSION....22

III. REORDER POINT, SAFETY LEVEL, BASE STOCK LEVEL, AND ECONOMIC RETENTION QUANTITY CALCULATION....25
A. PROBLEM STATEMENT....25
B. INFORMED FOUNDATION....27
1. Demand Variability....27
a. Normal Distribution....27
b. Poisson Distribution....29
2. Inventory Cost....29
3. Reorder Point and Safety Level....30
a. Reorder Point (Constant Demand)....30
b. Reorder Point (Irregular Demand)....30
c. Reorder Point and Safety Stock (Normal Distribution)....32

d. Reorder Point and Safety Stock (Poisson Distribution)........33
e. Reorder Point and Safety Stock (Normal Approximation to Poisson)..........35
4. Base Stock Level..........35
a. Economic Order Quantity..........36
b. Reorder Quantity..........37
5. Stockage Criteria..........39
a. Marine Corps Stockage Criteria..........39
b. Dollar-banding..........40
6. Excess Retention..........42
C. DATA ANALYSIS..........44
1. Data Collection..........44
2. Data Analysis..........44
a. Demand Variability..........44
b. Reorder Point and Safety Level..........45
c. Reorder Quantity..........48
d. Stockage Criteria..........49
D. INVENTORY MANAGEMENT SIMULATION..........53
1. Simulation Overview..........53
2. Simulation Results..........56
E. CONCLUSION..........59
IV. OPERATIONAL AVAILABILITY..........63
A. BACKGROUND..........63
B. OPERATIONAL AVAILABILITY..........66
C. AN INTEGRATED APPROACH FOR DECREASING MEAN SUPPLY RESPONSE TIME..........67
D. CONCLUSION..........70
V. CONCLUSION AND RECOMMENDATIONS..........73
A. CONCLUSION..........73
B. SUGGESTIONS FOR FUTURE RESEARCH..........77
APPENDIX A..........79
APPENDIX B..........83
APPENDIX C..........85
APPENDIX D..........87
LIST OF REFERENCES..........89
INITIAL DISTRIBUTION LIST..........91

LIST OF FIGURES

Figure 1. Retail Demand File 5
Figure 2. Moving Average 7
Figure 3. Weighted Moving Average..9
Figure 4. Exponential Smoothing..10
Figure 5. Smoothing Parameter...11
Figure 6. Exponential Smoothing with Trend 12
Figure 7. Trumpet of Doom 13
Figure 8. Four Components of Demand Forecast 14
Figure 9. Increasing Variability of Orders up the Supply Chain...............................16
Figure 10. Forecast Methods with Smallest Forecast Error 21
Figure 11. Normal Distribution..28
Figure 12. Mean Demand during Periods of Demand (Poisson distribution) 31
Figure 13. Reorder Point and Safety Level (From: Professor Kenneth Doerr)...........33
Figure 14. Poisson Distribution (From: Professor Keebom Kang) 34
Figure 15. Order Quantity Size (From: Professor Kenneth Doerr).............................36
Figure 16. Stockout Probability Composition of Base Stock Level............................38
Figure 17. Stockout Probability versus Days of Supply Reorder Point 47
Figure 18. Stockout Probability versus Days of Supply Base Stock Level 49
Figure 19. Service Levels Dollar-banded based on Item Criticality, Demand, and Cost 51
Figure 20. Summary of Inventory Level and Excess Calculations per Inventory Method 53
Figure 21. Inventory Management Simulation Screenshot 55
Figure 22. Custom Distribution for Simulating Demand Size 56
Figure 23. Simulated Average Stockouts per Inventory Method 58
Figure 24. Simulated Average Inventory Value per Inventory Method......................58
Figure 25. Inventory Reviews, Excess Reporting, and Inventory Manager Turnover......61
Figure 26. Hockey Stick Effect Illustration (from Geraldo Ferrer) 65
Figure 27. DoD Monthly O&M Obligation Rates (1977-1990) 65
Figure 28. An Integrated Approach for Decreasing Mean Supply Response Time..........68

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LIST OF TABLES

Table 1. Data Collection Summary..18
Table 2. Moving Average Forecast Summary 18
Table 3. Weighted Moving Average Forecast Summary..19
Table 4. Exponential Smoothing Forecast Summary..20
Table 5. Exponential Smoothing with Trend Forecast Summary..................................20
Table 6. Items Forecasted to Have No Demand in the Next Period.............................22
Table 7. Inventory Levels Expressed as Days of Supply..25
Table 8. Data Collection Summary..44
Table 9. Force Activity Designator Including Shipment Times (from: DLA Handbook)..46
Table 10. Days of Supply Model Classification 48
Table 11. Proposed Marine Corps' Stockage Criterion 50
Table 12. Dollar-banded Service Levels for Critical Items 50
Table 13. Dollar-banded Service Levels for Non-critical Items......................................51
Table 14. Inventory Management Simulation Results..57
Table 15. Acquisition Advice Codes (from: DLA Customer Assistance Hand Book)....81
Table 16. Materiel Identification Codes (from: UM-4400-124).....................................83
Table 17. Combat Essentiality Codes (from: UM-4400-124)..85
Table 18. Recoverability Codes (from: UM-4400-124) 87

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I. INTRODUCTION

A. BACKGROUND

> Since 1990, the Government Accountability Office has designated DoD inventory management as a high-risk area due to ineffective and inefficient inventory systems and practices. The problems that were found via audits revealed that throughout DoD, there is a substantial amount of on-hand inventory that is not needed to meet required inventory levels.[1]

Specifically, DoD inventory levels frequently exceed customer requirements in some areas, while failing to satisfy customer requirements in others. Moreover, supply inventory levels have grown by 35 percent from $63.3 billion in fiscal year 2001 to $85.6 billion in fiscal year 2006.[2] One reason for excess inventory throughout DoD is use of the Days of Supply methodology for determining inventory levels. Other reasons include, but are not limited to:

1. The continual use of outdated supply and maintenance legacy systems.
2. The overemphasis throughout DoD on stockpiling inventory to achieve readiness as opposed to improving the responsiveness of the supply chain.
3. The budget culture of DoD which seeks to expend annual resources as opposed to driving down operational expenses.

Since the 1970s, DoD has used the Days of Supply model to determine inventory levels, which is based on multiples of the average daily demand for an item.[3] Essentially, inventory levels are expressed in terms of average monthly demand and the order-ship-time (also referred to as lead time). The combination of these three variables results in a prescribed inventory level that is supposed to support customer demand over a set period of time (e.g., 30 days, 60 days, and etc.).

In theory, the Days of Supply model prescribes an inventory level that will satisfy customer demand over a specified period of time. Nevertheless, the Days of Supply model has its shortcomings, which are provided below.

---

[1] GAO Report (2007).

[2] Ibid.

[3] Fricker and Robbins (2000), p. 9.

1. The Days of Supply model assumes that demand is relatively constant as opposed to variable. This is evident in how the Days of Supply model averages down demand by eliminating high and low months of demand as opposed to averaging all periods of demand. Specifically, the Days of Supply model assumes that high and low months of demand are not legitimate and therefore should be excluded. However, in many instances, these months may indeed be valid periods of demands. Consequently, reorder points and safety levels are often too low, which results in frequent stockouts and persistent backorders.

2. The Days of Supply model does not use a probabilistic method to compute the reorder point and safety level. Instead, the Days of Supply model strictly uses multiples of mean demand. The reorder point is simply mean demand during lead time plus the safety level. The safety level is expressed in terms of 15 or 30 days of mean demand for non-critical or critical items, respectively. To be more specific, 15 or 30 days of mean demand translates to 50 or 100 percent of average monthly demand, respectively. The safety level is always 15 or 30 days depending on the criticality of the item.

3. The Days of Supply model's safety level is often vulnerable to the magnitude of mean demand during lead time. For instance, if a non-critical item has a lead time of 15 days and a safety level of 15 days, then the reorder point and safety level is based upon a multiple of 30 days (i.e., 15 days lead time + 15 days safety level), which translates to 100 percent average monthly demand. If the service level of the Days of Supply reorder point and safety level is statistically measured against a mean demand during lead time computation based upon all periods with demand (to include the high and low months), then in many instances the service level achieved by the Days of Supply methodology is substandard. Moreover, the inflexibility of the 15 and 30 day safety level parameters complicate the ability of the inventory manager to prescribe specific service levels (e.g., 99-percent service level for all items under $10). This further complicates the incorporation of cost into the inventory management decision.

4. The Days of Supply model overemphasizes the importance of the retail-level of supply rather than the entire supply chain that is supposed to function as a system of interrelated parts. This is evident in the Days of Supply model's computation of the

reorder quantity, which ranges from 20 to 60 days of mean demand (i.e., 66 to 200 percent of average monthly demand). Specifically, the Days of Supply model seeks to optimize its own area by carrying excess inventory as opposed to leveraging the capabilities of each member in the supply chain, which will minimize total inventory cost (i.e., ordering and holding costs).

These problems form the basis for three important inventory management questions:

1. What to order?
2. How much to order?
3. When to order?[4]

The answer to these three questions depends on the methods used to effectively measure demand variability and compute inventory levels. This forms the basis for the stockout probability inventory model.

B. OBJECTIVE

The goal of this project is to develop a consumable inventory management strategy for the Supply Management Unit (SMU) that will be applicable to other DoD supply support organizations. The SMU is a Marine Corps wholesale activity that provides Class IX (consumable repair part) supply support to 160 Marine Corps units. The SMU uses the Days of Supply model to establish requisitioning objectives and reorder points, which are based upon historical usage, lead time, and supply data. Historical data is generated from Class I Natural Programs that were designed in the early 1970s. Since then, inventory management has evolved from warehouses packed with supplies to warehouses carrying just enough inventories to satisfy customer demand. The evolution of inventory management has proven that there is a direct relationship between inventory and cost in that the ability to efficiently manage inventory serves as a catalyst for reducing cost. Efficient inventory management involves the ability to accurately forecast demand, prudently establish inventory levels, and provide optimal customer support, while minimizing the system-wide costs of the supply chain. Therefore, this

[4] Fricker and Robbins (2000), pp. xiii-xiv.

project will focus on developing an inventory management strategy that will efficiently balance readiness with supply chain system-wide costs. Specifically, this project will address methods that the SMU can use to accurately:

1. Forecast Demand
2. Establish Inventory Levels
3. Improve Readiness
4. Eliminate Excess Inventory

C. METHODOLOGY

The project group will develop a consumable inventory management strategy for the SMU by incorporating operations management, business modeling, simulation, supply chain management, and logistics engineering concepts that pertain to inventory management. During this project, the Days of Supply model will be compared to the stockout probability model. First, the project group will collect a sample of the SMU's current inventory. Then, the project group will forecast this sample via the moving average, weighted moving average, and exponential smoothing. This will provide the SMU with an appraisal of various alternatives for conducting trend analysis with demand data. Next, the project group will measure demand variability in order to determine the appropriate stockout probability method (i.e., normal or Poisson distribution) to use for calculating the reorder quantity, reorder point, and safety level. Once this has been determined, the project group will recompute new inventory levels for the sample via the DOS and stockout probability methods. Finally, the project group will test the validity of the DOS model and the stockout probability model in a simulation. This will enable the project group to assess average stock outs, average ordering costs, average holding costs, average inventory levels, and fill rates. This will comprise the consumable inventory management strategy.

II. FORECASTING DEMAND

A. PROBLEM STATEMENT

The Supply Management Unit (SMU) uses an arithmetic mean to forecast demand, which is compiled from twelve months of historical usage data. In calculating the arithmetic mean, the month with the highest demand (called a "spike") and the month with the lowest demand are removed from the equation. The remaining months are used to calculate an average, which is later used to calculate inventory levels.

Figure 1 provides an illustration of the Retail Demand File, which is used to calculate the average demand. The Retail Demand File consists of twelve months of historical usage data. The report is broken out into hits and demands, which are labeled "HITS" and "DMD" respectively. Hits reflect the total requisitions per month whereas demand reflects the total quantity ordered per month.

> It is important to understand that "1/12" is the previous month; <u>not</u> the month of January. For example, 2/12 is two months ago, 3/12 is three months ago, and etc. In month 5/12, it is noted that the demand quantity is 16. Every other month is either four or zero. Month 5/12 would be considered a spike in demand. In this case, the highest month would be manually crossed out (month 5/12) along with the lowest month (any month 1/12 through 6/12). Months 7/12 through 12/12 are not considered in this example, since these periods had zero demand. The remaining demand quantities would be averaged over four months. This calculation is the Average Monthly Recurring Demand (AMRD). In this case, the AMRD is four.[5]

SAMPLE RETAIL DEMAND

PRIME OR SUB NSN NOMEN	RQMT CODE CEC	RO MO	QTY ALW	OH QTY	AMRD	HITS DMD 1/12	HITS DMD 2/12	HITS DMD 3/12	HITS DMD 4/12	HITS DMD 5/12	HITS DMD 6/12	HITS DMD 7/12	HITS DMD 8/12	HITS DMD 9/12	HITS DMD 10/12	HITS DMD 11/12	HITS DMD 12/12
4820-01-222-0332	3GIF	5			3	4	4	4	4	4	4						
VALVE, ROTARY	5			3		4	4	4	4	16	4						

Figure 1. Retail Demand File

5 Standard Operating Procedures (April 2007).

The calculation of the AMRD in Figure 1 is an unconventional method of smoothing demand in order to calculate an arithmetic mean. Although the smoothing process results in an average with a smaller standard deviation, the elimination of spikes ignores the effects of trend or seasonality, which may result from deployment cycles, maintenance surges, and etc. Additionally, this forecasting method does not produce measurements that indicate the level of forecast error or the risk associated with fluctuations in demand. Consequently, the absence of these measurements often results in either carrying too much inventory or not enough. Therefore, the SMU needs to implement time-series forecasting techniques such as the moving average, weighted moving average, exponential smoothing, or exponential smoothing with trend, which will factor in fluctuations in demand.[6] These forecasting methods will enable the SMU to accurately forecast demand. This is essential for conducting trend analysis and establishing criteria for stocking new items, managing existing items, or phasing out obsolete items. Furthermore, these methods will enable the SMU to quantify the magnitude of the error associated with the forecast method.

B. INFORMED FOUNDATION

1. Forecasting Methods

a. Moving Average

> Moving averages (MA) smooth out variations when forecasting demands are fairly steady. MA is useful providing that demand will remain relatively constant over time. A four period moving average can be calculated by summing the past four periods of demand and dividing the total by four. By adding the most recent months demand to the sum of the previous four months and dropping the earliest period, a moving average is created. This can be expressed as:
>
> *k*-period moving average = Σ(Actual values in previous *k* periods) / *k*.[7]

[6] "Time-series models assume that the past is an indication of the future. Time-series models rely on quantitative data. Time series models attempt to predict the future by using historical data. These models make the assumption that what happens in the future is an indication of what has happened in the past." Balakrishnan, Render, and Stair (2007), p. 529.

[7] Balakrishnan, Render, and Stair (2007), p. 534.

The MA is a relatively simple method for forecasting demand; however, the MA tends to over- and under-react to fluctuations in demand. For example, Figure 2 provides an illustration of a 4-period moving average in which the forecast horizon is four weeks. Based upon period nine's forecast, demand is predicted to be thirteen in period ten. The actual demand in period ten is eighteen; therefore, the forecast underestimated actual demand by a value of five. Subsequently, period ten's forecast for period eleven is ten. The actual demand in period eleven is nine; therefore, the forecast overestimated demand by a value of one. This example demonstrates how fluctuations in actual demand impair the accuracy of the moving average's forecast. In short, as demand variability increases, relative forecast accuracy decreases. Conversely, as demand variability decreases, relative forecast accuracy increases.

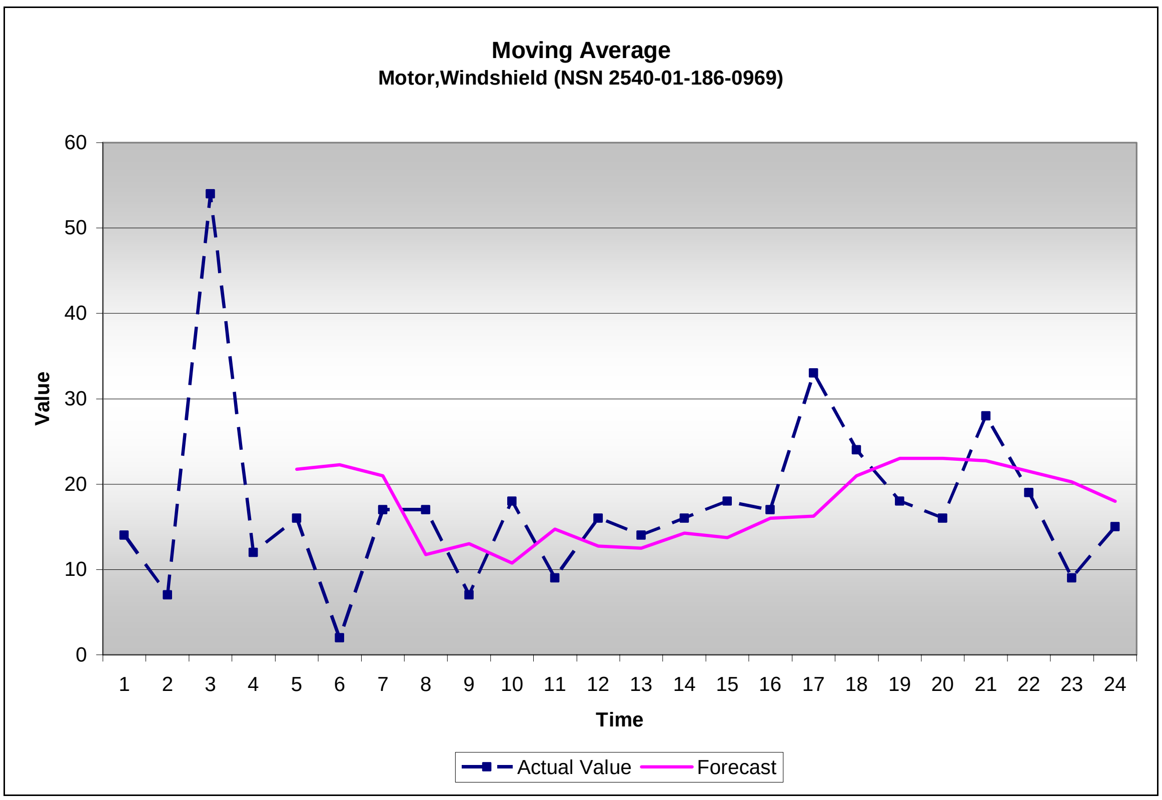

Figure 2. Moving Average

b. Weighted Moving Average

Weighted Moving Average (WMA) is a moving average forecasting method that places different weights on different past values. In the regular moving average approach, all the input data are assumed to be equally important. For example, in a three-period model, data for all three previous periods are given equal importance, and a simple average of the three values is computed. In some cases, however, data for some periods (e.g., recent periods) may be more important than data for other periods (e.g., earlier periods). This is especially true if there is a trend or a pattern in the data. In such cases, we can use weights to place more emphasis on some periods and less emphasis on others. Weighted Moving Average is expressed as follows:

$$= \frac{\sum_{i=1}^{k} (\text{weight fo r period } i\,) \times (\text{actual va lue in per iod } i)}{\sum_{i=1}^{k} (\text{weights})}$$

k-period weighted moving average forecast. [8]

Figure 3 provides an example of how the weighted moving average places different weights on each period of demand data.

[8] Balakrishnan, Render, and Stair (2007), p. 539.

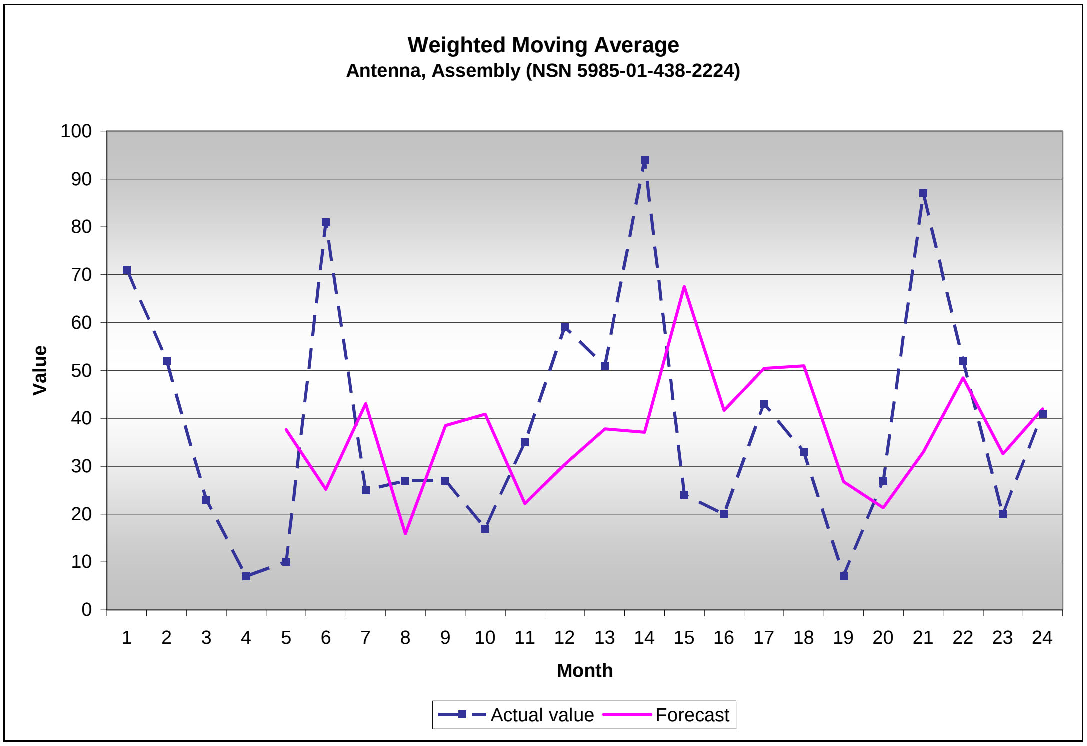

Figure 3. Weighted Moving Average

c. Exponential Smoothing

Both moving averages and weighted moving averages are effective in smoothing out sudden fluctuations in the demand pattern in order to provide stable estimates. In fact, increasing the size of *k* (i.e., the number of periods averaged) smooths out fluctuations even better. However, doing so requires maintaining extensive records of past data. An alternate forecasting approach that is also a type of moving average technique, but requires little record keeping of past data is called exponential smoothing. 9

Exponential smoothing involves determining the amount of weight assigned to recent demand as opposed to previous observations, with respect to the overall variability of demand. The exponential smoothing forecast is expressed as:

Forecast for period (t+1) = forecast for period t + $\alpha \times$ (actual value in period t – forecast for period t)

[9] Balakrishnan, Render, and Stair (2007), p. 543.

A shorter way to express this formula is:

$F_{t+1} = F_t + \alpha(A_t - F_t)$

Figure 4 provides an example of how exponential smoothing smoothes outs fluctuations in demand.

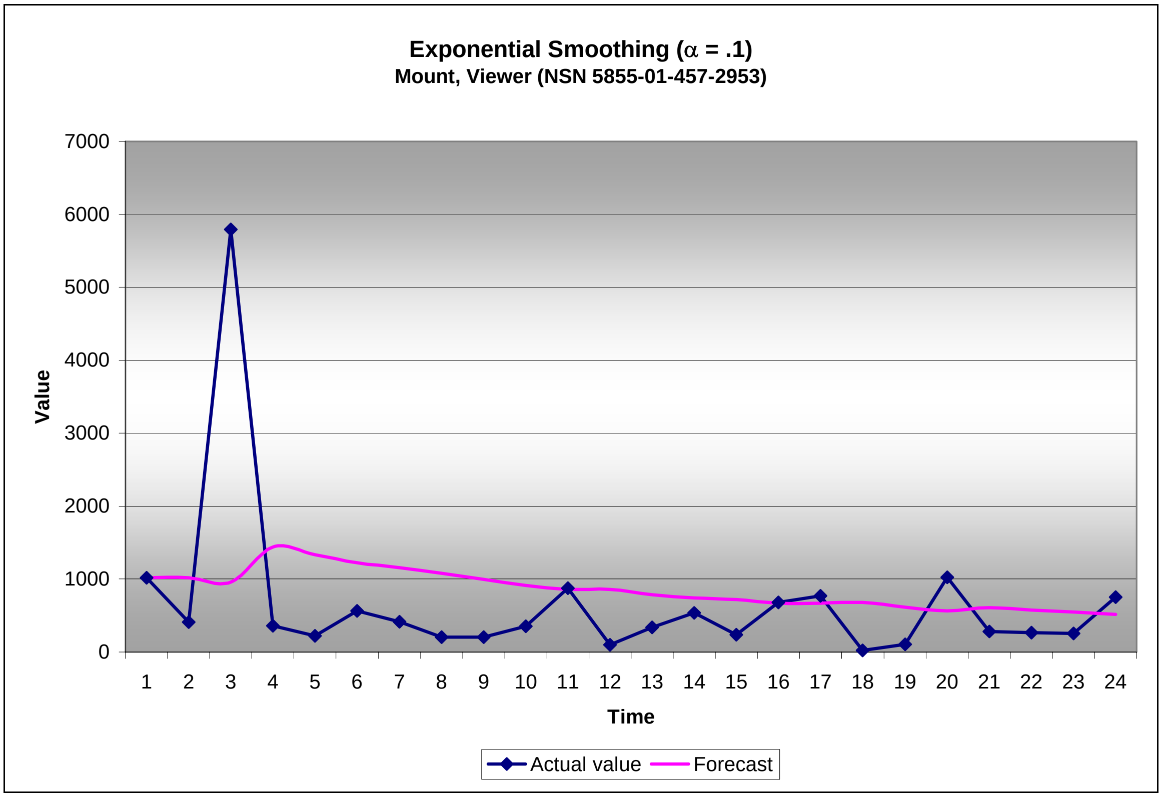

Figure 4. Exponential Smoothing

The α is a weight commonly referred to as the smoothing constant that has a value between 0 and 1, inclusive. This value determines the amount of forecast error that is acceptable based upon previous forecasts. For example, a smoothing constant of 0.8 is considered more responsive to demand fluctuations as the smoothing constant gives significant weight to recent demand. Consequently, the higher the variability of demand, the more the forecast tends to exaggerate fluctuations in the forecasts. Conversely, a smoothing constant of 0.2 gives little weight recent demand, which tends to be less responsive fluctuations in demand. Figure 5 provides an example of how the smoothing constant establishes an acceptable level of forecast error in order to smooth out fluctuations in demand.

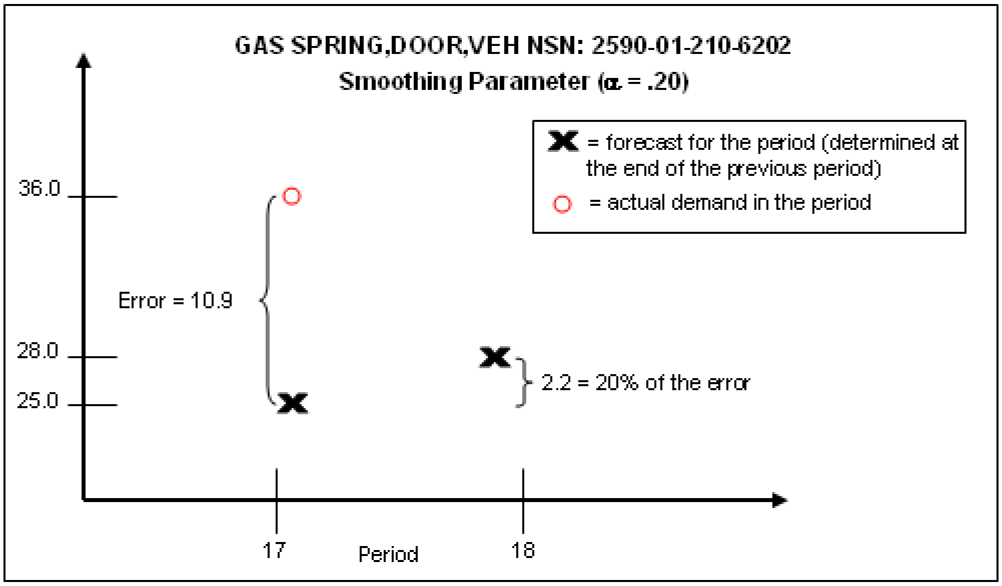

Figure 5. Smoothing Parameter[10]

d. Exponential Smoothing with Trend

Similar to α, β is a weight commonly referred to as the trend constant that has a value between 0 and 1, inclusive. Similar to α, this value determines the amount of forecast error that is acceptable based upon previous forecasts; however, the trend constant adjusts the forecast to emphasize trend. For example, a trend constant of 0.8 is considered more responsive to demand fluctuations as the trend constant gives significant weight to recent demand. Consequently, the higher the variability of demand, the more the forecast tends to exaggerate fluctuations in the forecasts. Conversely, a trend constant of 0.2 gives little weight recent demand, which tends to be less responsive fluctuations in demand. Figure 6 provides an example of exponential smoothing with trend. Exponential smoothing with trend is expressed as:

1. $F_t = S_{t-1} + b_{t-1}$ where $S_t = \alpha\ D_t + (1-\alpha)\ F_t$ and $S_1 = D_1$
2. $b_t = \beta\ (S_t - S_{t-1}) + (1-\beta)\ b_t$-1 where $b_1 = D_2 - D_1$

---

[10] Ferrer (2007a), p. 118.

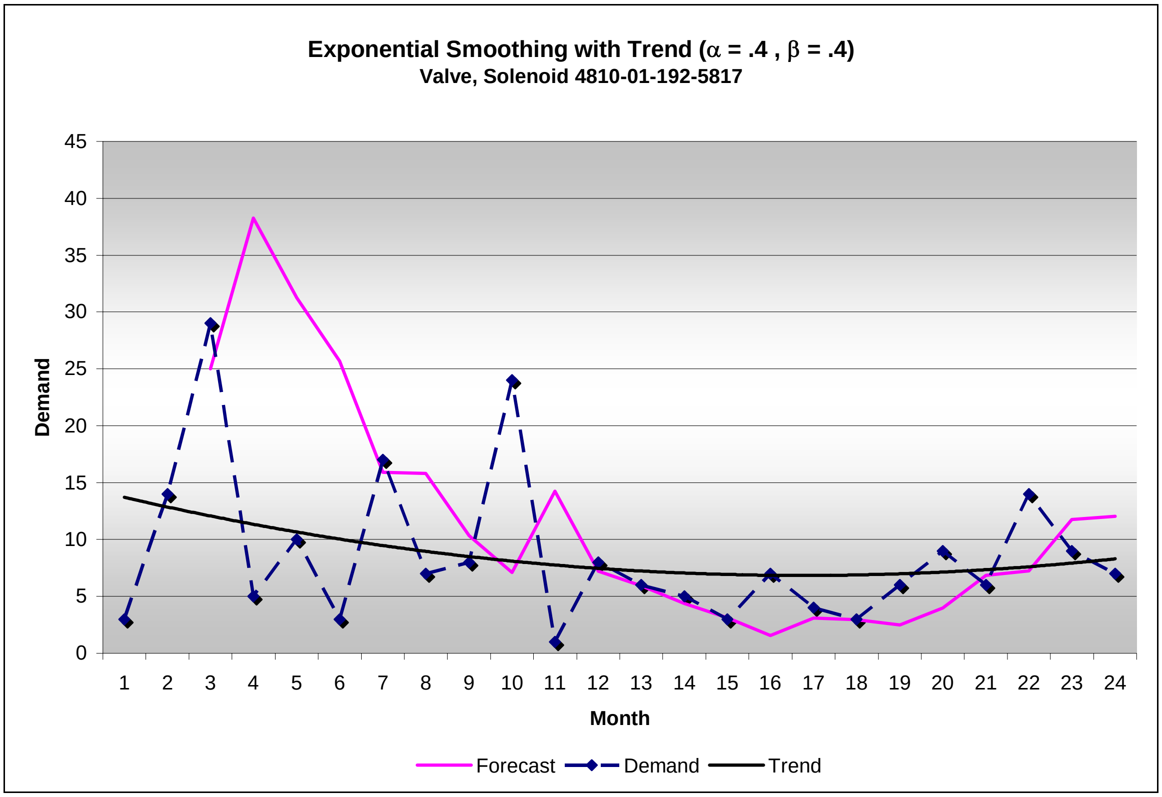

Figure 6. Exponential Smoothing with Trend

2. Basic Guidelines

Whenever an inventory manager is forecasting demand, there are three basic guidelines that should always be considered:

1. The forecast is always wrong.
2. The longer the forecast horizon, the worse the forecast.
3. Aggregate forecasts are more accurate.[11]

a. *First Guideline*

The first guideline is based upon the fact a forecast is a prediction of future demand. This estimation is solely based on historical demand. Simply put, it is impossible to precisely determine demand via forecasting. However, forecasting serves as an indication of what future demand may be. Therefore, forecasting is a useful tool for inventory planning purposes.

[11] Ferrer (2007a), p. 48.

b. Second Guideline

The second guideline is based upon a concept called the "Trumpet of Doom," which suggests that "as the forecast horizon increases, forecast accuracy decreases (illustrated in Figure 7). This principle gets its name from a "trumpet" showing forecast accuracy decreasing as the time until the forecast event increases."[12] Simply put, short-term forecasts are more relevant and accurate than long-term forecasts. Specifically, short-term forecasts serve to predict the immediate future, such as demand in the following day, week, or month. Conversely, long-term forecasts are generally used for projects that entail significant startup costs with subsequent operational expenses, such as development plans for a distribution facility. Therefore, short-term forecasts are more appropriate for forecasting demand.

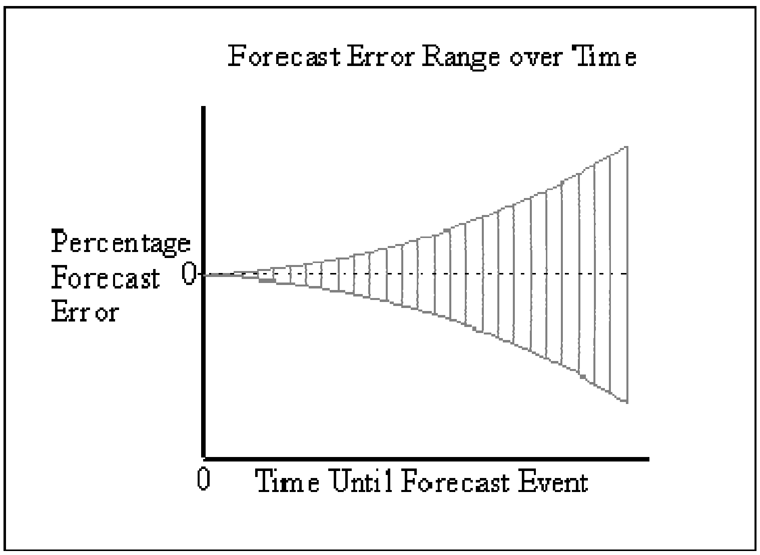

Figure 7. Trumpet of Doom[13]

c. Third Guideline

Aggregate forecasting involves an inventory manager using various forecasting methods to determine demand patterns rather than a single approach. Collectively, various forecasting methods will provide a more accurate estimate with

[12] Ferrer (2007a), p. 104.

[13] Ferrer (2007b), p. 21.

special consideration given to minimizing the overall forecast error. Subsequently, aggregate forecasting enables an inventory manager to effectively contrast the results from each forecast method.

3. Four Components of a Demand Forecast

Besides the basic guidelines, it is important for an inventory manager to understand the four components of a demand forecast (illustrated in Figure 8):

1. Mean Demand – average demand.
2. Trend – rate of increase/decrease in demand over time (without seasonality).
3. Seasonality – one or more patterns in demand, repeating on a cyclic basis.
4. Randomness – unexplained variation over time.[14]

Mean demand, trend, and seasonality can all be accounted for via certain forecast methods, such as exponential smoothing. However, the only component that can not be accounted for is randomness. Randomness validates the first guideline, which states that the forecast is always wrong. The inaccuracy of the forecast results in forecast error, which "indicates how well the model performed against itself using past data.[15]

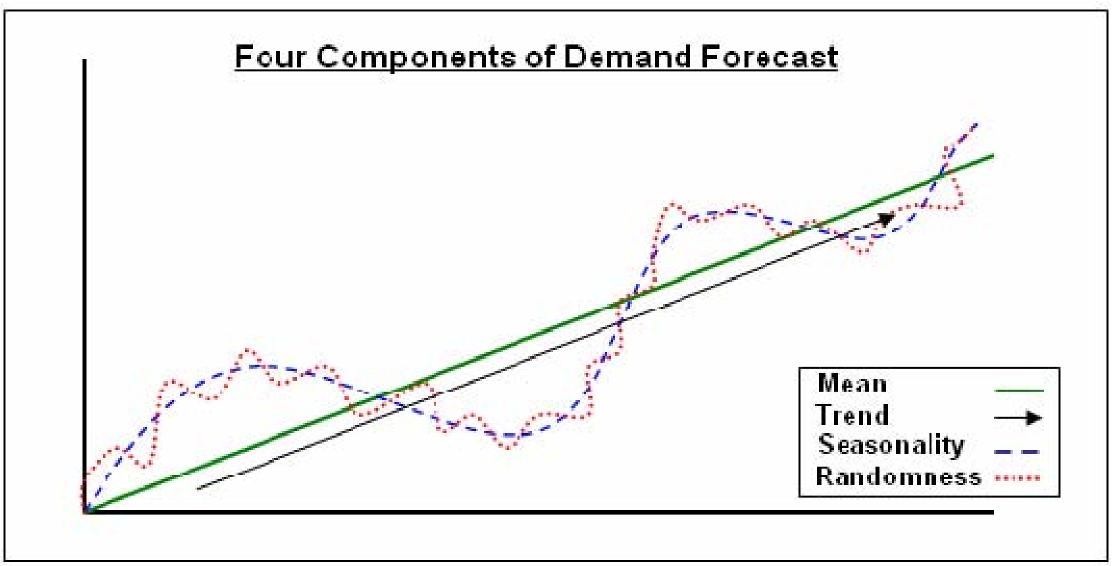

Figure 8. Four Components of Demand Forecast

[14] Ferrer (2007a), p. 113.

[15] Balakrishnan, Render, and Stair (2007), p. 531.

4. Measurements of Forecast Error

There are three measurements that an inventory manager can use to determine the magnitude of forecast error:

1. Mean Absolute Deviation (MAD) – computed as the average of the absolute values of the individual forecast errors.[16]
2. Mean Squared Error (MSE) – computed as the average of the squared values of the individual forecast errors. A drawback of using MSE is that it tends to accentuate large deviations due to the squared term. For example, if the forecast error for period 1 is twice as large as the error for period 2, the squared error in period 1 is four times as large as that for period 2. Hence, using MSE as the measure indicates that we prefer to have several smaller deviations rather than one large deviation.[17]
3. Mean Absolute Percent Error (MAPE) – computed as the average of the absolute difference between the forecasted and actual values, which expresses the error as a percentage of the actual values. A problem with both the MAD and MSE is that their values depend on the magnitude of the item being forecast. If the item is measured in thousands, the MAD and MSE can be very large. To avoid this problem, we can use the MAPE.[18]

5. The Bullwhip Effect

At the end user-level, demand variability is relatively low. Nevertheless, demand variability tends to increase significantly as orders travel up the supply chain from the retailer to the supplier. Consequently, excess inventory levels and back-orders are prominent throughout the supply chain. This is attributed to a phenomenon called the "bullwhip effect." The bullwhip effect occurs when one entity in the supply chain over reacts to an increase in demand. This over reaction causes all entities further up the supply chain to overreact by increasing their safety stock in order to compensate for growing fluctuations in demand. Figure 9 provides an illustration of how demand variability increases as demand travels up the supply chain.

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[16] Balakrishnan, Render, and Stair (2007), p. 531.

[17] Ibid., p. 532.

[18] Ibid.

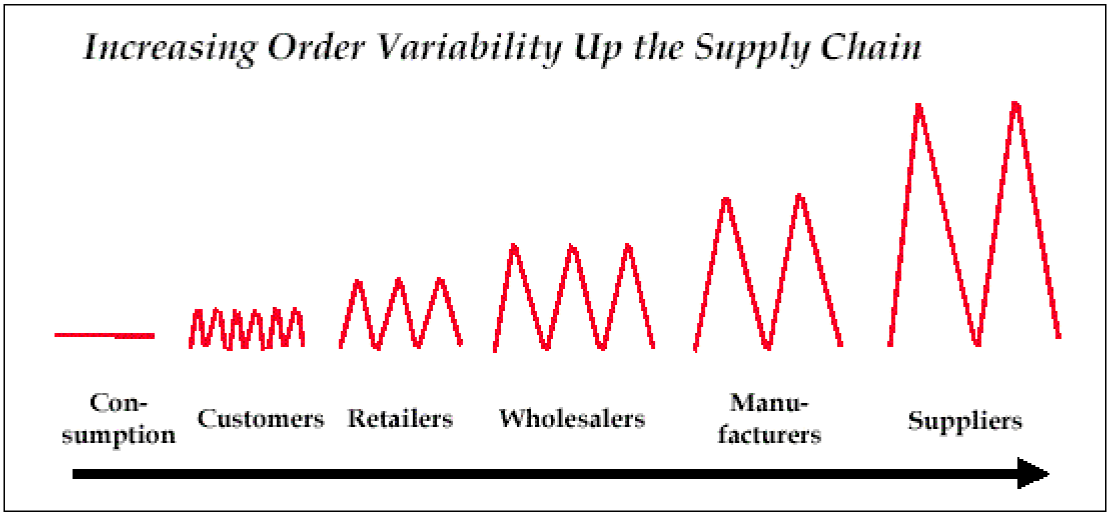

Figure 9. Increasing Variability of Orders up the Supply Chain[19]

For example; the typical retail supply chain will consist of a retailer, wholesalers, manufacturers, and suppliers. If the retailer does not accurately communicate why consumer demand has slightly increased, then the wholesaler may overact to an increase in the retailer's order size. This increase that originated at the retail-level will multiply itself throughout the supply chain as the wholesalers, manufacturers, and suppliers all increase their respective levels of safety stock to sustain future demands. The bullwhip effect can be mitigated by ensuring active communication throughout all levels of the supply chain. For instance, if the slightest increase in consumer demand was the result of a one week reduction in price by the retailer, then the retailer could avoid causing problems within the supply chain by letting the wholesaler know that the increase in order size is only temporary. This active communication cannot be overstressed. An active flow of information regarding end user demand from the SMU to DLA is crucial in preventing the bullwhip effect.

6. Expert Opinion Forecasting

Another way that the SMU can benefit from active communication is through frequent dialogue with end users. In general, the SMU's customer service section engages in frequent dialogue with customers with regards to demand management (i.e.,

[19] Rollins College (2007).

troubleshooting supply related reports and order processing). Recently, the SMU has begun to use the customer service section to solicit input from units with regards to critical items. This initiative should be encouraged by senior leadership as the customer service section is an effective means for customers to provide the SMU with firsthand knowledge as to which items are absolutely critical. When likened to the commercial sector, the customer service section is merely a marketing agency that has the capability of forecasting demand based upon customer feedback as opposed to strictly demand data.

It is inevitable that some rare situations will develop where all available forecasting models predict a decline in the usage of an item, but the end users' knowledge says the exact opposite. End user input regarding future needs are based off of training schedules or some other type of factual information that can aid in the inventory management decision. However, the inventory manager must critically examine feedback as end users tend to overestimate future requirements, which results in excess inventory. Many times end users will purposely overestimate the requirements for certain critical parts in order to be "safe." Nonetheless, the desire to be "safe" often depletes funding that can be used to purchase items that have frequent demand.

C. DATA COLLECTION AND ANALYSIS

1. Data Collection

The SMU provided the project group with a Retail Demand File (dated April 2007), which the project group used to collect data. First, the project group determined the overall population of the SMU's inventory, which consisted of 19,833 items valued at $37,181,832. Then, the project group reviewed the preceding 12 months and subtracted 7,211 items that had zero demand. This provided the project group with an adjusted population size of 12,622 items valued at $29,189,577. Next, the project group determined that a sample size of 984 was required in order to obtain a confidence level of ninety-five percent and a confidence interval of three. For simplicity, the project group rounded the sample size from 984 to 1,000. Based upon this calculation, the project group collected the sample from the first 1,000 items in the SMU's inventory (sorted from most to least expensive). This sample collection method enabled the project group to obtain a sample that represented 82 percent of the SMU's inventory value. Finally, the project group developed spreadsheet models to forecast the sample via moving average, weighted moving average, and exponential smoothing. A summary of the data collected is provided in Table 1.

	Quantity	Value
Initial population size	19,833	$37,181,832
Total items removed from population due to insufficient demand data	7,211	$7,992,254
Adjusted population size (after removing items with insufficient demand data)	12,622	$29,189,577
Sample Size (82% of total inventory value)	1000	$23,804,226

Table 1. Data Collection Summary

2. Data Analysis

a. Moving Average

The project group used a 4-period MA to forecast 24 months of historical demand data, which consisted of a sample of 1,000 items from the SMU's inventory. The justification for using 4-periods was based on the premise that 4-periods would not over- or under-react to fluctuations as much as a 2-period or 6-period MA, respectively. The results of the forecast predict that 376 items (valued at $6,220,948) would have zero demand in the next period. Based upon the sample size, it can be inferred that 37.6 percent of the overall inventory will have zero demand in the next period. If this demand pattern continues in subsequent periods, an inventory reduction maybe required, which would decrease the population size from 12,622 to 7,876. A summary of the data collected is provided in Table 2.

Sample Size	1000
Items forecasted to have zero demand in the next period (#)	376
Items forecasted to have zero demand in the next period (%)	37.60%
Value of the Sample Size	$23,804,226
Value of items forecasted to have zero demand in the next period	$6,220,948
Value of items forecasted to have positive demand in the next period	$17,583,277

Table 2. Moving Average Forecast Summary

b. Weighted Moving Average

Using a 4-period WMA, the project group forecasted a sample of 1,000 items from the SMU's inventory. The justification for using 4-periods was based on the premise that 4-periods would not over- or under-react to fluctuations as much as a 2-period or 6-period WMA, respectively. Each item was forecasted via a Microsoft Solver Excel model whereas various weights were assigned to each of the four periods until the MSE was minimized. The results of the forecast predict that 441 items (valued at $8,121,433) would have zero demand in the next period. Based upon the sample size, it can be inferred that 44.1 percent of the overall inventory will have zero demand in the next period. If this demand pattern continues in subsequent periods, an inventory reduction maybe required, which would decrease the population size from 12,622 to 7,076. A summary of the data collected is provided in Table 3.

Sample Size	1000
Items forecasted to have zero demand in the next period (#)	441
Items forecasted to have zero demand in the next period (%)	44.10%
Value of the Sample Size	$23,804,226
Value of items forecasted to have zero demand in the next period	$8,121,433
Value of items forecasted to have positive demand in the next period	$15,682,793

Table 3. Weighted Moving Average Forecast Summary

c. Exponential Smoothing

Using an exponential smoothing model that utilized a smoothing from 0.1 to 0.4, the project group forecasted a sample of 1,000 items from the SMU's inventory. Each item was forecasted via a Microsoft Solver Excel model whereas various smoothing constants were assigned to each item in order to minimize the MSE. The results of the forecast predicted that 361 items (valued at $6,230,724) would have zero demand in the next period. Based upon the sample size, it can be inferred that 36.1 percent of the overall inventory will have zero demand in the next period. If this demand pattern continues in subsequent periods, an inventory reduction maybe required, which would decrease the population size from 12,622 to 8,065. A summary of the data collected is provided in Table 4.

Sample Size	1000
Items forecasted to have zero demand in the next period (#)	361
Items forecasted to have zero demand in the next period (%)	36.10%
Value of the Sample Size	$23,804,226
Value of items forecasted to have zero demand in the next period	$6,230,724
Value of items forecasted to have positive demand in the next period	$17,573,502

Table 4. Exponential Smoothing Forecast Summary

d. Exponential Smoothing with Trend

Using an exponential smoothing with trend model that utilized smoothing and trend constants from 0.1 to 0.4, the project group forecasted a sample of 1,000 items from the SMU's inventory. Each item was forecasted via a Microsoft Solver Excel model whereas various smoothing and trend constants were assigned to each item in order to minimize the MSE. The results of the forecast predicted that 437 items (valued at $9,019,498) would have zero demand in the next period. Based upon the sample size, it can be inferred that 43.7 percent of the overall inventory will have zero demand in the next period. If this demand pattern continues in subsequent periods, an inventory reduction maybe required, which would decrease the population size from 12,622 to 7,206. A summary of the data collected is provided in Table 5.

Sample Size	1000
Items forecasted to have zero demand in the next period (#)	437
Items forecasted to have zero demand in the next period (%)	43.70%
Value of the Sample Size	$23,804,226
Value of items forecasted to have zero demand in the next period	$9,019,498
Value of items forecasted to have positive demand in the next period	$14,784,728

Table 5. Exponential Smoothing with Trend Forecast Summary

3. Summary

Figure 10 shows the optimal forecasting methods based upon a sample of 1,000. Based upon these findings, weighted moving average and exponential smoothing prove to be the best forecasting methods for this particular sample as these methods had the lowest forecast error 64.2- and 28.9 percent of the time, respectively. Exponential smoothing with trend had the lowest forecast error 6.7 percent, which indicates that only 6.7 percent of the items forecasted have a trend. Moving average had the lowest forecast error only 2 percent of the time, which indicates that moving average is the least preferred forecasting method for this particular sample. However, in the absence of sophisticated software (e.g., Microsoft Excel Solver), the moving average forecast method can be used for simplicity.

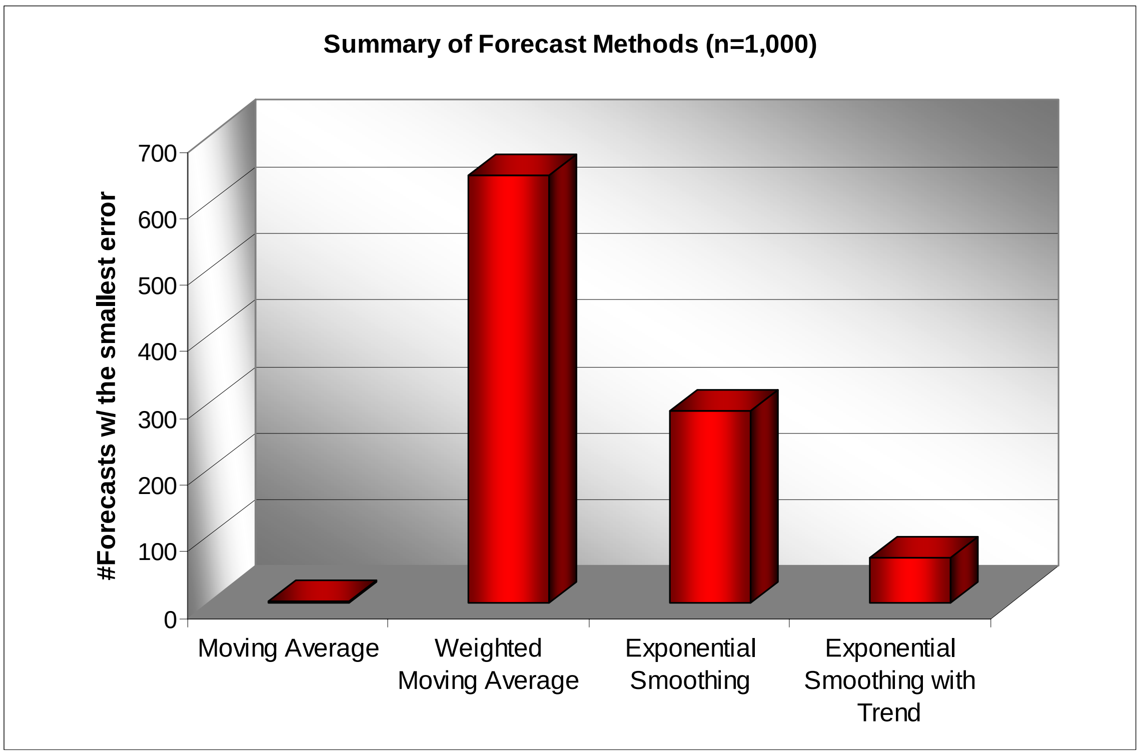

Figure 10. Forecast Methods with Smallest Forecast Error

Table 6 provides a summary of the forecast methods with regards to the forecasted demand for the next period. Based upon the four forecasting methods, approximately 36.1 – 44.1 percent of the overall inventory is expected to have zero demand in the next period. These items need to be continually reviewed in order to determine if an inventory reduction is warranted. Specifically, the inventory manager needs to examine these items in terms of criticality in order to determine if these items need to be removed from inventory. Based upon the forecast results alone, an inventory reduction of 40.38 – 62.05 percent is possible. This is based upon average forecasts for the next period, which were derived from the three forecasting methods.

Forecasting Method	Initial Population Size	Items w/ no Usage	Adjusted Population Size	Sample Size	Items Forecasted to Have No Demand	Adj. Population Forecasted to Have No Demand	Population Forecasted to Have No Demand
Moving Average	19,833	7,211	12,622	1,000	376	37.60%	60.29%
Weighted Moving Average	19,833	7,211	12,622	1,000	441	44.10%	64.42%
Exponential Smoothing	19,833	7,211	12,622	1,000	361	36.10%	59.33%
Exponential Smoothing w/ Trend	19,833	7,211	12,622	1,000	437	43.70%	64.17%
					Average	40.38%	62.05%

Table 6. Items Forecasted to Have No Demand in the Next Period

D. CONCLUSION

In this chapter, the project group discussed and utilized the following forecasting methods:

1. Moving Average
2. Weighted Moving Average
3. Exponential Smoothing
4. Exponential Smoothing with Trend.

Each of these methods provides the SMU with alternatives for conducting trend analysis, while predicting demand in the next period. Moreover, these forecasting methods provide the SMU with a means of measuring forecast error. As indicated in the results, the simplest method that the SMU can use is a moving average. However, weighted moving average and exponential smoothing forecasts appear to be more accurate. Therefore, the project group recommends that the SMU use all four methods in order to determine the forecast with the least amount of forecast error. Moreover, the SMU should focus on the forecast with the least amount of forecast error; regardless of the forecast method.

It is important to note that forecasting methods do not contribute directly to the calculation of Economic Order Quantities (EOQ), Reorder Points (ROP), or Safety Levels (SL). However, forecasting provides an inventory manager with insight as to which direction demand is trending; upwards, downwards, or steady. In addition, forecasting provides an inventory manager with a baseline for determining whether or not to stock an item. In terms of determining inventory levels, forecasting is most useful in providing upstream suppliers in the supply chain (i.e., Defense Logistics Agency or DLA) with anticipated demand data. The sharing of demand-related data with upstream suppliers reduces demand uncertainty and subsequent demand variability throughout the supply chain. Therefore, it is recommended that the SMU provides DLA with a monthly Retail Demand File with aggregate forecasts for subsequent periods.

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III. REORDER POINT, SAFETY LEVEL, BASE STOCK LEVEL, AND ECONOMIC RETENTION QUANTITY CALCULATION

A. PROBLEM STATEMENT

The SMU uses the Days of Supply model to determine inventory levels, which is based on multiples of the average daily demand for an item.[20] Essentially, inventory levels are expressed in terms of average monthly demand, the frequency of monthly demand, and the order-ship-time (also referred to as lead time). The combination of these three variables results in a prescribed inventory level that is supposed to support customer demand over a specified period of time (e.g., 30 days, 60 days, etc.). For instance, Table 7 provides an example of an item that has an average monthly demand of 10, a total of 10 months with demand, and an average order-ship-time of 10 days. Based upon these parameters, the Days of Supply model would prescribe an inventory level of 55 Days of Supply, which translates to a requisitioning objective of 18 and a reorder point of 8 for non-critical items. If the item is critical, then a safety factor of 30 Days of Supply would be added to the reorder point, which would increase the requisitioning objective from 18 to 23 (i.e., 70 DOS). In general, the safety level is always prescribed as 15 or 30 days of expected demand for non-critical or critical items, respectively. Although this methodology simplifies safety level computation, it fails to accurately establish inventory levels based on stockout probability. Expressly, since demand variability is not measured, inventory managers are prevented from using a Normal or Poisson distribution to calculate safety levels.

				DOS		MULTIPLIER			RESULT		
	CWT (DAYS)	MONTHS W/HITS	RQMT CODE	RO DAYS	ROP DAYS	RO	ROP	SAFETY LEVEL	RO	ROP	SAFETY LEVEL
CRITICAL ITEM	6 - 10	>9	3FBF	70	40	2.33	1.33	0.43	23.3	13	4
NON-CRITICAL ITEM	7 - 10	>9	3FBC	55	25	1.83	0.83		18.3	8	

Table 7. Inventory Levels Expressed as Days of Supply

[20] Fricker and Robbins (2000), p. 9.

The Days of Supply model is consists of three basic components:

1. Operating level (synonymous with reorder quantity or requisitioning objective)
2. Reorder point
3. Safety level.

The operating level is simply the reorder quantity. This amount, when added to the reorder point and safety level, establishes the requisitioning objective. Typically, the operating level ranges from 20 to 60 days worth of expected demand (depending on usage and lead time). Historically, the Marine Corps has mandated the SMU maintain operating level of no more than 60 days of supply, which amounts to two months of expected demand per replenishment order. Specifically, each time a replenishment buy is initiated, a reorder quantity of up to two months expected demand may be procured. In general, calculating the operating level is fairly simple. However, it completely ignores the costs of ordering and holding inventory. For instance, a 60-day operating level maybe feasible for a relatively inexpensive item with a high transportation cost. However, a 20-day operating level may be more appropriate for an expensive item with a relatively low transportation cost.

In general, the Days of Supply's reorder point calculation is accurate, especially since it is based on expected demand during lead time. In fact, the Days of Supply model is not hindered by its computation of the reorder point, but rather its non-probabilistic computation of the safety level. As mentioned previously, the Days of Supply model excludes demand variability from the safety level computation, which prohibits the use of Normal or Poisson distributions. Consequently, inventory managers using the Days of Supply methodology are limited in their ability to accurately measure and mitigate the risk of inventory stockouts. Moreover, it is difficult to incorporate cost into the prescription of safety levels, which is imperative in minimizing inventory expenses.

Based upon the stated limitations of the Days of Supply model, the focus of this chapter will be on demonstrating how the SMU can incorporate demand variability into the reorder quantity, reorder point, and safety level computations. Moreover, this chapter will highlight the feasibility of probabilistic inventory computation methods via an inventory simulation. Specifically, this simulation will incorporate demand and lead time variability to illustrate the importance of measuring demand variability.

Besides discussing probabilistic inventory computational methods, this chapter will concentrate on the SMU's inventory stockage criteria. Specifically, this chapter will discuss item criticality, item attainability, item classification, demand frequency, and item cost. This will enable the SMU to make informed decisions with regards to which items are suitable for inventory stockage.

Lastly, this chapter will address excess inventory determination, retention, and depletion. Expressly, this chapter will provide the SMU with insight as to how to successfully eliminate excess inventory, while concurrently minimizing inventory expenses and mitigating risk.

B. INFORMED FOUNDATION

1. Demand Variability

Before establishing inventory levels, the inventory manager must effectively measure demand variability. Specifically, the inventory manager needs to determine whether the demand data follows a normal or a Poisson distribution. Identifying the distribution type is essential for determining the method for calculating the Reorder Point and Safety Level. Failure to accurately distinguish the distribution of demand data may result in either carrying too much inventory or not enough.

a. Normal Distribution

"A normal distribution is a continuous bell-shaped distribution that is a function of two parameters, the mean (μ) and the standard deviation (σ) of the distribution."[21] The focus of the normal distribution is the standard deviation, which provides insight as to what extent demand data varies from the mean. "As the standard deviation becomes smaller, the normal distribution becomes steeper," which indicates

[21] Balakrishnan, Render, and Stair (2007), p. 614.

that demand is relatively steady.[22] "When the standard deviation becomes larger, the normal distribution has a tendency to flatten out or become broader," which indicates that demand is relatively unstable.[23]

> The standard deviation depends somewhat on the magnitude of the observations in the data set. If the observations are in the millions, a standard deviation of 10 would probably be considered a small number. On the other hand, if the observations are less than 50, the standard deviation would be seen as a large number. The logic behind this lies behind yet another measure of variability, the coefficient of variation. The coefficient of variation of a set of observations is the standard deviation the observations divided by the mean. [24]

Figure 11 provides an example of a normally distributed demand item with a coefficient of variation (CV) of 37 percent.

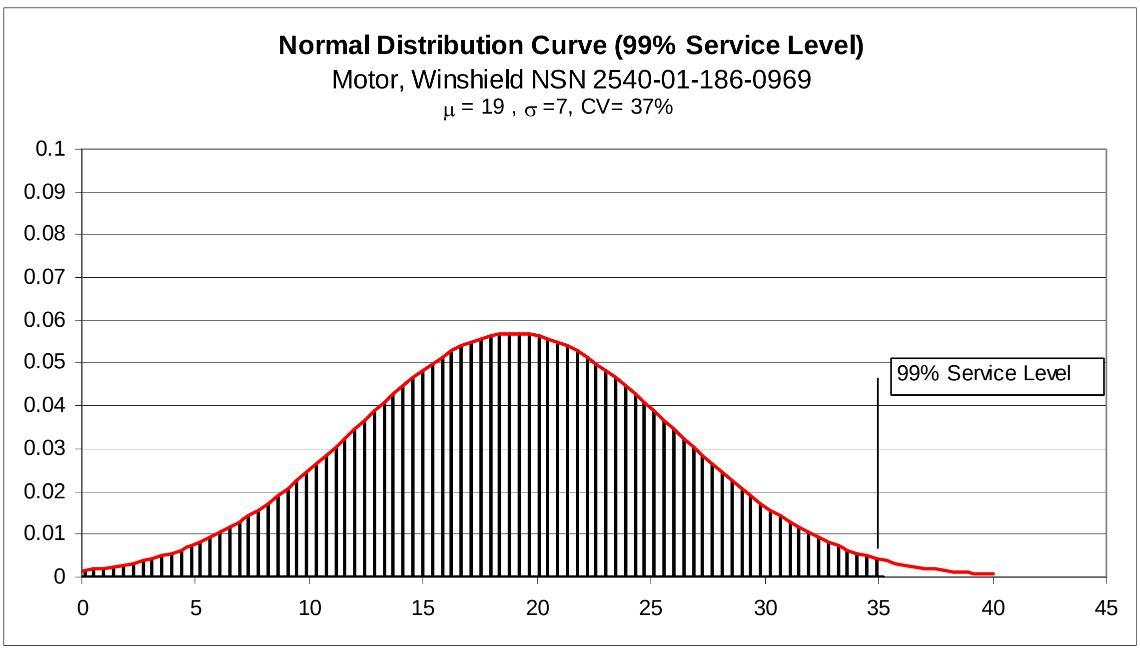

Figure 11. Normal Distribution

[22] Balakrishnan, Render, and Stair (2007), p. 614.

[23] Ibid.

[24] Keller (2007), p. 105.

b. Poisson Distribution

The Poisson distribution is frequently used by logistics engineers as a means to conduct spare parts management. Since the demand for repair parts is typically driven by the frequency of maintenance failures, the use of a Poisson distribution is generally more appropriate for spare parts management than a normal distribution, especially since maintenance failures are infrequent. The irregularity of maintenance failures is largely attributed to maintenance actions (i.e., preventative and corrective maintenance) that are taken to mitigate and eliminate the root causes of failures.

2. Inventory Cost

Once the distribution of demand data has been identified, the inventory manager may decide to incorporate inventory cost and calculate an EOQ. This decision depends entirely on the magnitude of variation in demand data. If demand is highly variable, then it is inappropriate to incorporate cost, since the Economic Order Quantity will change dramatically each time a replenishment order is initiated. Under these conditions, it is more appropriate to determine a reorder quantity based on the probability of stockout. Conversely, if demand is somewhat constant, then the relevant cost of buying and holding inventory should be determined and used to compute an EOQ. In general, the four types of inventory costs are holding costs, ordering costs, setup costs, and shortage costs. Since the SMU does not manufacture items and shortage costs are generally measured in terms of backorders, this project will just briefly discuss holding costs and ordering costs.

1. **Holding (or carrying costs).** This broad category includes the costs for storage facilities, handling, insurance, pilferage, breakage, obsolescence, depreciation, taxes, and the opportunity cost of capital. Obviously, high holding costs tend to favor low inventory levels and frequent replenishment.
2. **Ordering costs.** These costs refer to the managerial and clerical costs to prepare the purchase or production order. Ordering costs include all the details, such as counting items and calculating order quantities. These costs associated with maintaining the system needed to track orders are also included in ordering costs.[25]

[25] Apte et al. (2006), pp. 136-137.

3. Reorder Point and Safety Level

a. Reorder Point (Constant Demand)

Once the inventory manager has identified the demand distribution (i.e., Normal or Poisson), then the inventory manager can effectively compute the reorder point and safety level. Moreover, the demand distribution predetermines the calculation of the SL, which is subsequently added to the reorder point. When the inventory position (i.e., on-hand + due in – due out) drops to the reorder point, stock replenishment is initiated to prevent an inventory stockout. Specifically, the reorder point is designed to sustain mean demand during lead time.

If the reorder point assumes constant demand and lead time, then the reorder point is simply

$$R = \bar{d}L$$

where

$\bar{d} =$ Average daily demand (constant)

$L =$ Lead time in days (constant).[26]

For example, if the annual demand for an item is 1000, then the average daily demand is 2.74 units (i.e., 1,000 ÷ 365 days). If the lead time is 14 days, then the reorder point computes to 38.36 or 38 units (i.e., 2.74 units per day * 14 days lead time).

b. Reorder Point (Irregular Demand)

In most situations for the SMU, demand is not constant. Hence, it is important that the inventory manager distinguish between periods with and without demand in calculating average daily demand. The reason being is that periods without demand average down periods with demand, which results in reorder points and safety levels that are too low. Similarly, demand is also averaged down when high and low months are excluded from the calculation of mean demand, which results in reorder points and safety levels that are too low. Averaging down demand is a major short-coming of the Days of Supply model, which explains why stockouts are a recurring problem.

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[26] Apte et al. (2006), pp. 136-137.

For example, in Figure 12 there are eight months with demand, four months without demand, and the desired service level is 95 percent. If the high and low months are excluded, then the Days of Supply average rounded up amounts to four. Based upon a lead time of 127 days, the Days of Supply mean demand during lead time equals 17. After adding a 30-day safety level to mean demand during lead time, the reorder point totals to 21. However, if all periods with demand are averaged, then the average rounded up amounts to five. Based upon a mean demand during lead time of 21 that is calculated using all periods with demand, the Poisson distribution calculates a reorder point of 29. Consequently, averaging all periods with demand enables an inventory manager to achieve a 96.26 percent service level as opposed to the Days of Supply average, which only results in a 55.77 percent service level. Therefore, the inventory manager should always consider all periods with demand when computing mean demand. Moreover, the inventory manager should always assume that demand is not constant when computing daily mean demand by only averaging periods with demand. Even if demand is constant, the formula for computing daily mean demand for irregular demand will produce the same results as the formula for computing daily mean demand for constant demand.

Poisson cumulative distribution versus Days of Supply Model (NSN: 6150-01-144-2920)																				
DOS Average	Actual Average	DOS MDDLT	Actual MDDLT	DOS ROP	Poisson ROP	Desired Service Level	DOS Achieved Service Level	Poisson Achieved Service Level	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Month 7	Month 8	Month 9	Month 10	Month 11	Month 12	Lead Time
4	5	17	21	21	29	95.00%	55.77%	96.26%	0	11	4	2	0	0	0	5	3	1	4	5	127

Figure 12. Mean Demand during Periods of Demand (Poisson distribution)

If the inventory manager assumes that demand is not constant, then the reorder point is simply:

$$R = \bar{d}L$$

where

$\bar{d} =$ daily mean demand during periods with demand (irregular)

$L =$ Lead time in days (constant).

Daily mean demand during periods with demand is simply:

$$\text{Average Daily Demand} = \frac{\text{Total Annual Demand}}{\text{n} * (365 \div 12)}$$

where

n = number of months with demand

c. Reorder Point and Safety Stock (Normal Distribution)

Safety stock is the amount of inventory carried in addition to the reorder point, which is designed to prevent a potential inventory stockout during replenishment. Moreover, the amount of safety stock carried translates to the service level, which can be determined via a normal or Poisson distribution.[27]

If demand is normally distributed, then the safety level is simply:

$$SL = z\sigma_L$$

where

$z =$ Number of standard deviations for a specified probability
$\sigma_L =$ Standard deviation of demand during lead time.[28]

For instance, suppose that mean demand (μ_D or $\bar{d}$) is 100, the standard deviation of demand (σ_D) is 10, lead time (L) is 14 days, and the desired service level is 95 percent (or probability that a stockout will not occur during lead time). The mean demand during lead time (μ_L) computes to 1400 based upon the following:

$$\mu_L = \mu_D * L$$

The standard deviation of demand during lead time (σ_L) would compute to 37.41 based upon the following:

$$\sigma_L = \sigma_D * \sqrt{L}$$

On the normal distribution table, the required z-value to obtain the 95-percent service level amounts to 1.645. When the z-value multiplied against σ_L, the safety level

[27] Apte et al. (2006), p. 146.

[28] Ibid., p. 147.

computes to 61.55 or 62 units. Subsequently, the reorder point (including SL) totals to 1462 (i.e., 1400 + 62). Figure 13 provides an illustration of the reorder point and safety level.

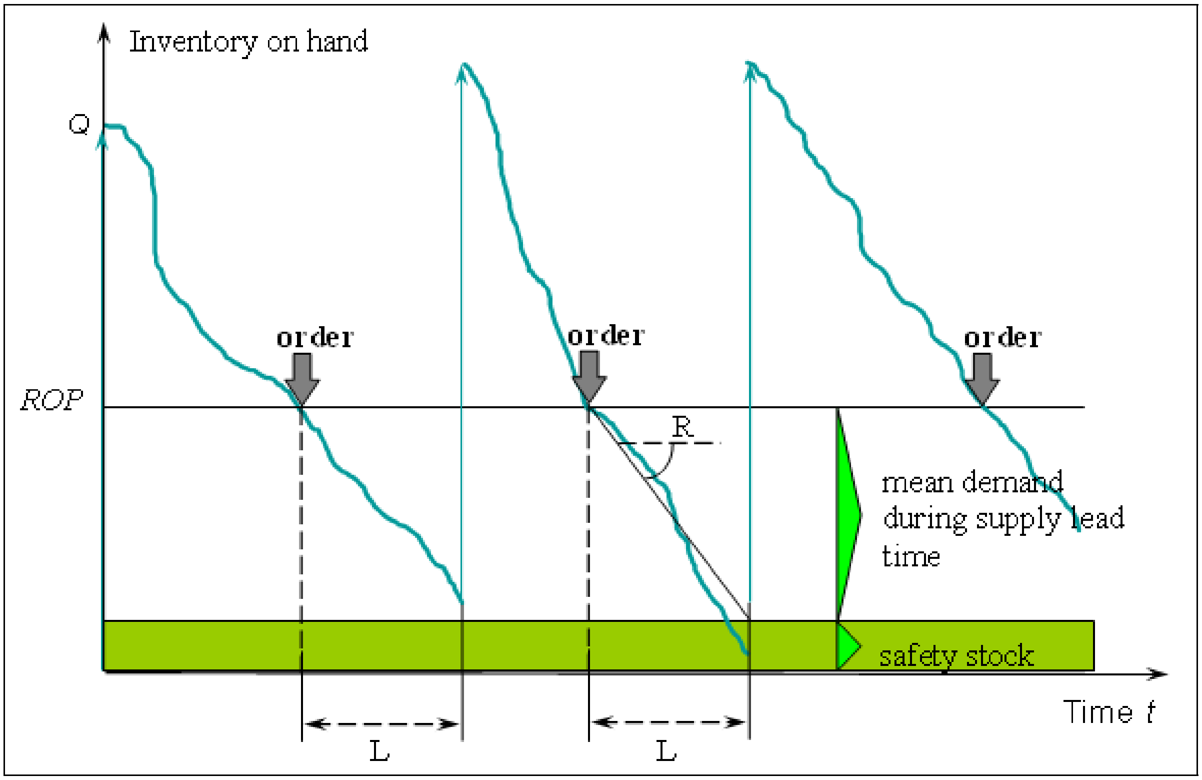

Figure 13. Reorder Point and Safety Level (From: Professor Kenneth Doerr)

d. Reorder Point and Safety Stock (Poisson Distribution)

If demand follows a Poisson distribution, then it is more appropriate to compute the reorder point and safety level via a Poisson distribution. The reason being is that the standard deviation is unusually large, which implies that demand fluctuates considerably. Consequently, if the safety level is computed under the assumption that demand is normally distributed, then the safety level will be extremely large. Moreover, this erroneous safety level assumes that demand is relatively constant, which presents a substantial risk of carrying too much inventory. Therefore, the Poisson method enables the inventory manager to discount the abnormalities (or spikes) in demand and compute a reorder point and safety level based upon mean demand.

For simplicity, an inventory manager can user Microsoft Excel to determine the reorder point and safety level for a demand item that follows a Poisson distribution. Figure 14 provides an example of how an inventory manager can use Microsoft Excel to compute the reorder point and safety level. In this situation, mean demand (μ_D or $\bar{d}$) is 100, lead time (L) is 14 days, and the desired service level is 95 percent. The daily mean demand during periods with demand multiplied by lead time amounts to 1400 (i.e., 100 * 14 days). Based upon the desired service level, the Poisson distribution returns a value of 1,462 units, which consists of both the reorder point and safety level.

To find x that satisfies Pr (X ≤ x) = p		
mean	1400	(daily mean demand during periods with demand * lead time)
p	95%	(Protection level)
x	1462	Required Number of Repair Parts (i.e. Reorder Point + Safety Level)
P(X <=x)	x	
0	-1	
0.0000	0	
0.0000	1	
0.0000	2	
0.0000	3	
0.9371	1457	
0.9403	1458	
0.9434	1459	
0.9463	1460	
0.9491	1461	
0.9518	1462	
0.9544	1463	
0.9569	1464	
0.9592	1465	
0.9615	1466	
0.9636	1467	

> **Protection Level:**
> =POISSON(Reorder Point + Safety Level,daily mean demand during periods with demand * lead time,1)

Figure 14. Poisson Distribution (From: Professor Keebom Kang)

e. Reorder Point and Safety Stock (Normal Approximation to Poisson)

Whenever mean demand is greater than or equal to 30, the normal distribution can be used to approximate the Poisson distribution in computing the reorder point and safety level. The value of the mean and the variance of a Poisson distribution are the same. Therefore,

$\mu = \sigma^2$, or $\sigma = \sqrt{\mu}$.

The computation of the reorder point and safety level via normal approximation is simply:

$$\text{Average Daily Demand * Lead Time} + z * \sqrt{\text{Average Daily Demand * Lead Time}}$$

4. Base Stock Level

Once the inventory manager has computed the reorder point and safety level, the inventory manager must establish the base stock level. Base stock level is also referred to as requisitioning objective or RO, which is the "maximum amount of inventory that will be on hand or on order to sustain operations."[29] There are two methods that an inventory manager can use to determine the base stock level. The first is the economic order quantity, which incorporates the relevant costs of holding and ordering inventory. If demand is fairly constant, then an inventory manager can use this method to calculate replenishment order quantities that will minimize total inventory cost. Conversely, if demand is not constant, then it is more appropriate to calculate a reorder quantity based upon stockout probability. Stockout probability is the second method for establishing the base stock level, which involves adding the mean demand during periods with demand to the reorder point. Since this method is based solely on mean demand during periods with demand as opposed to cost, it is relatively easier to implement than the economic order quantity method.

[29] Marine Corps Order (1992), p. A-8.

a. Economic Order Quantity

If demand is fairly constant, then an inventory manager can compute an economic order quantity by determining the relevant costs of holding and ordering inventory. As illustrated in Figure 15, the objective of the economic order quantity is to minimize the total annual costs of inventory, which consist of the annual holding cost and the annual ordering cost. The economic order quantity is expressed as:

$$EOQ = \sqrt{\frac{2DS}{iC}} \quad \text{where}$$

D = Annual demand
S = Ordering Cost
i = Rate of Holding Cost (e.g., government bond rate)
C = Cost per Unit[30]

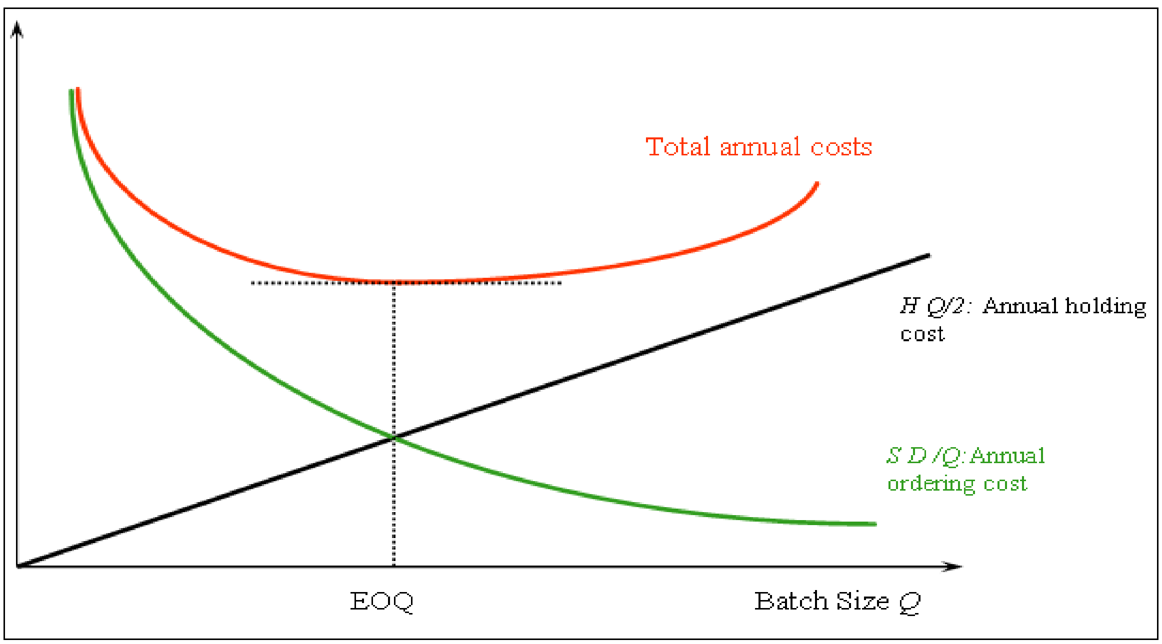

Figure 15. Order Quantity Size (From: Professor Kenneth Doerr)

For example, suppose an item has an annual demand (D) of 10,000, an ordering cost (S) of $100, a unit cost (C) of $20, and an opportunity cost (i) of 20 percent. The economic order quantity would compute to 707 units. If the ordering cost were to decrease to $40,

[30] Apte et al. (2006), p. 154.

then the economic order quantity would also decrease to 447 units. This demonstrates how high ordering costs, favor large and few replenishment orders as opposed to low ordering costs favoring small and frequent replenishment orders. Large replenishment orders tend to increase inventory levels, while decreasing transportation costs. Conversely, small replenishment orders tend to decrease inventory levels, while increasing transportation costs. Clearly, this illustrates the continual trade-off between inventory and transportation costs in which the Days of Supply model does not consider. Providing that demand is fairly constant, then the economic order quantity method will enable an inventory manager to minimize the costs of ordering and holding inventory, which will have a measurable effect on transportation costs. Conversely, if demand is not constant, then a stockout probability model is more appropriate.

b. Reorder Quantity

When demand is unpredictable, a reorder order quantity based upon stockout probability should be used instead of an economic order quantity. The reason being is that economic order quantity assumes that the reorder order quantity will remain constant as demand remains constant. In the case of the SMU, demand often fluctuates considerably, which nullifies the validity of the economic order quantity. Therefore, a reorder order quantity based on stockout probability is more appropriate than an economic order quantity. The stockout probability method involves adding mean demand during periods with demand to the reorder point. Despite the fact that this method doesn't incorporate holding or ordering costs into the reorder quantity, this method naturally achieves the same effect as the EOQ. The reason being is that expected annual demand is uniformly distributed into equal batch sizes, which consist of monthly expected demand. Consequently, this enables the inventory manager to efficiently balance holding and ordering costs. For instance, if an inventory manager were to set the reorder quantity to weekly mean demand (i.e., Annual Demand ÷ 52 Weeks or Weeks with Demand), then the inventory manager would have a lower inventory level, but a significantly higher transportation cost. Conversely, if the inventory manager set the reorder quantity equal to annual demand, then the inventory manager would have a significantly higher inventory level, but lower transportation cost. These two examples provide insight as to why an inventory manager should use monthly expected demand as the reorder quantity, since this will effectively balance transportation and inventory costs.

Regardless of whether demand follows a normal or Poisson distribution, mean demand will always constitute the center of the distribution. As illustrated in Figure 16, the reorder point and safety level constitute the area from mean demand to the specified area under the right side of the curve. Similarly, the reorder order quantity constitutes the area from mean demand to the area under the left side of the curve. Collectively, the reorder order quantity, reorder point, and safety level comprise the base stock level.

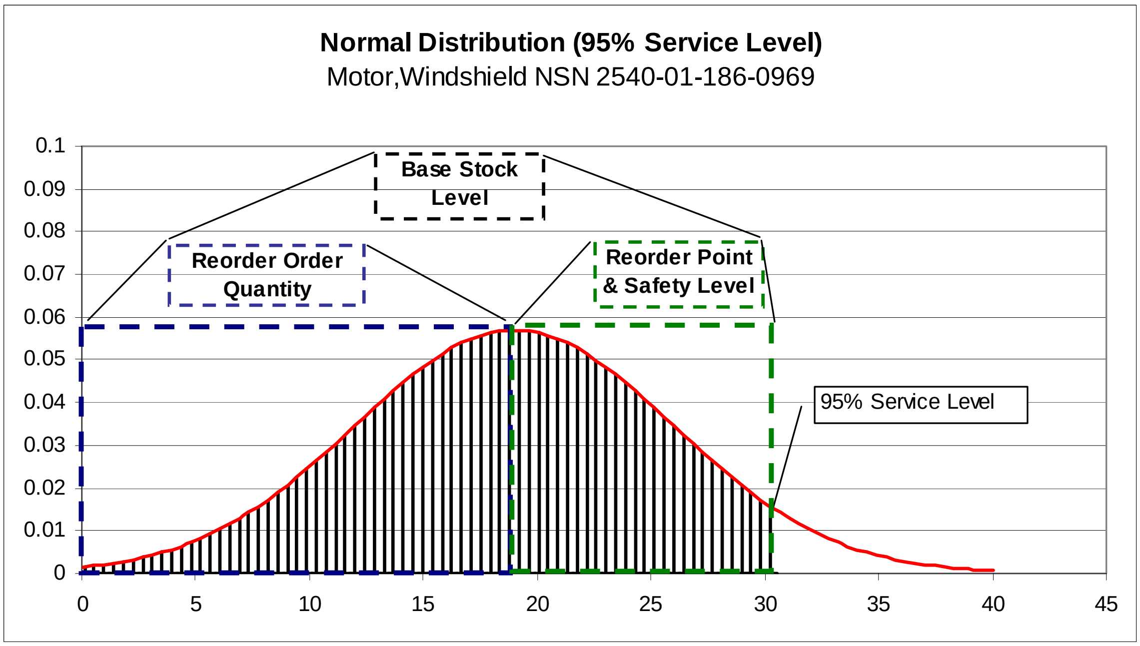

Figure 16. Stockout Probability Composition of Base Stock Level

The stockout probability method is a relatively straightforward, feasible method for establishing the base stock level. Also, since demand is often unpredictable, the stockout probability is generally a more appropriate method for determining the reorder quantity than the economic order quantity. Subsequently, this method is more practical for the SMU, since an inventory manager would not have to regularly compute ordering costs, such as labor and order processing. Additionally, the stockout probability method enables the inventory manager to prescribe specific service levels for various items. This enables the inventory manager to cost-effectively establish safety levels for items based upon both cost and criticality.

5. Stockage Criteria

a. Marine Corps Stockage Criteria

Currently, the Marine Corps provides the Supply Management Unit with two basic criteria for stocking an item.

> 1. Three recurring demands (issues) in 12 months are required to stock an item if the item is combat essential; e.g., Combat Essentiality Code (CEC) is 5 or 6.
>
> 2. Six recurring demands (issues) in 12 months are required to stock an item if it is not combat essential.[31]

In general, this stockage criterion is to some extent practical for critical items. Most commercial entities would not recommend stocking an item that only has three demands per year. However, for the military, operational readiness is significantly degraded when critical items are not available. Therefore, the ability to efficiently use criterion depends on the inventory methods used to compute inventory levels. Particularly, an inventory manager that uses this criterion should calculate inventory levels based upon the probability of stockout (i.e., normal or Poisson distribution).

The decision to begin stocking an item should be based on past and projected future usage. Moreover, the criticality of the item should determine the validity for stockage. For critical items, three months demand is somewhat feasible. However, the inventory manager should consult maintenance personnel to determine whether or not the item is absolutely crucial to preserving readiness, especially if the item is relatively expensive. Additionally, critical items should at a minimum be reviewed monthly in terms of availability and necessity.

For non-critical items, six or more months with demand within a twelve month time period should be sufficient justification for the SMU to begin stocking an

[31] Marine Corps Order (1992), p. 1-7.

item. If an item has an Acquisition Advice Code (AAC)[32] that indicates that it is readily available through DLA, another government activity, or the wholesale supply system, then the decision to stock an item is relatively easy; providing that there is sufficient demand. For items that are not readily available and have an AAC that indicates that acquisition will be difficult, a mid-level management decision must be made in order to determine if the particular item should be carried. This decision should be based on, but not limited to: availability of the item, funds available for purchase, and urgency of need by the requisitioning unit.

b. Dollar-banding

At face value, without consideration of demand frequency or the per unit cost of an item, an inventory manager could easily state that for critical and non-critical items, service levels of 99 and 95 percent are desired, respectively. However, the overall inventory value increases significantly as the unit cost increases, especially for items with an exceptionally high service level. In other words, if a critical item's demand frequency is low and the item's unit cost is high, then a high service level translates to a needless high inventory cost. The reason being is that the inventory manager is maintaining expensive inventory that is not justified by demand; especially when the item readily available from the supplier. Conversely, if a critical item's demand frequency is high and the item's unit cost is high, then a high service level is warranted. The same logic applies for non-critical items. The theory behind this is a concept defined by the RAND Corporation company as "dollar-banding" the inventory whereby it is more economical to stock many inexpensive items as opposed to few expensive items.[33]

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[32] DLA assigns Acquisition Advice Codes (AAC) to all items. An AAC is one of 26 alpha characters assigned to an item that indicates how and under what restrictions an item can be acquired by a government agency. There are basic methods of acquiring an item: (1) by requisition directly through DLA or another government entity; (2) by fabrication or assembly from raw materials; and (3) by direct purchase from civilian vendor. The terms and explanations of each AAC are contained in Appendix A.

[33] Fricker and Robbins (2000), p. 33.

> *Dollar banding* incorporates the price of an item in the inventory decision and allows the breadth of the inventory to be significantly increased for the same inventory investment. Essentially, the less expensive an item, the more liberal the inventory decision should be, leading to higher requisitioning objective/reorder point quantities. The idea is that stocking extra quantities of cheaper items is inexpensive insurance against surges in demand and the other types of variation inherent in the supply system. Dollar banding is often applied to great advantage by assuming a slightly higher risk of stock-out for a few low-demand, expensive items and using the savings to achieve significantly higher service levels for many inexpensive items.[34]

Based upon dollar-banding methodology, the RAND Corporation created three basic stockage criteria: 1. Simple Demand and Cost Rule; 2. Medium Demand and Cost Rule; and 3. Complicated Demand and Cost Rule. The "simple demand and cost rule" criteria are fairly liberal in the inventory decision, which is based primarily on demand frequency and cost. The "medium demand and cost rule, places cost restrictions on items with minimal usage, while relaxing restrictions on items with substantial usage."[35] The "complicated demand and cost rule that provides restrictions on expensive items, while relaxing restrictions on the cheaper items."[36]

> The simple demand and cost rule stocks an item if three or more demands occurred in the past year and the item had a unit price of less than $50 or if the item had six or more demands and any unit price.[37]
>
> The medium demand and cost rule stocks an item if it has
>
> 1. One or more demands and costs less than $10;
> 2. Two or more demands and costs less than $25;
> 3. Three or more demands and costs less than $50; or,
> 4. Six or more demands at any unit price.[38]

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34 Fricker and Robbins (2000), p. 33.

35 Ibid., p. 35.

36 Ibid.

37 Ibid.

38 Ibid.

The complicated demand and cost rule stocks an item if it has

1. One or more demands and costs less than $10;
2. Two or more demands and costs less than $50;
3. Four or more demands and costs less than $100;
4. Six or more demands and costs less than $500;
5. Eight or more demands and costs less than $2,500; or
6. Ten or more demands at any unit price.[39]

6. Excess Retention

Once an inventory manager has decided what items to stock and calculated the appropriate inventory levels, the inventory manager must effectively determine what portion of excess inventory is economical to keep and what portion should either be returned to the supplier for partial credit or sent to disposal. Specifically, the inventory manager needs to calculate the Economic Retention Quantity (ERQ). In many instances, current and projected consumption rates suggest that it is more economical to retain a certain portion of excess inventory as opposed to eliminating the entire excess inventory. This is based on the premise that retaining an economical portion of excess inventory will minimize the costs of having to reorder inventory at some point in the future. Moreover, current and projected consumption rates suggest that this economical portion of excess inventory will deplete itself over time and eventually reach the base stock level. Additionally, the retention of this economic portion of excess inventory provides a temporary buffer against sudden surges in demand, which would sometimes indicate that the base stock level is too low.

The first step an inventory manager needs to take in determining the excess retention quantity is to calculate the total excess quantity. This is simply

$$\text{Total Excess} = \text{Total On Hand} - \text{Base Stock Level}.$$

[39] Fricker and Robbins (2000), p 35.

Next, the inventory manager needs to determine the maximum allowable retention timeframe for the items declared excess. The current Marine Corps' policy for excess retention is as follows:

1. For those items that are combat essential (i.e., CEC of 5 or 6) or have a PWRMR, the authorized maximum retention limit is the sum of the RO and/or planned requirement and 24 months of stock at anticipated issue or wash-out rates.

2. If the prepositioned war reserve materiel stock (PWRMS) is not being commingled with operating stock, the authorized maximum retention limit is the sum of the RO, the PWRMR, and a maximum of 24 months of usage.

3. For those items which are not combat essential or do not have a PWRMR, the authorized maximum retention limit is 18 months of anticipated issue or wash-out rates.[40]

Based upon these criteria, an inventory manager can compute an excess retention quantity by simply

$$\text{Excess Retention Quantity} = \text{Annual Consumption} * \text{Allowable Retention Period}.$$

Lastly, an inventory manager can compute the returnable/disposable excess by simply

$$\text{Returnable/Disposable Excess} = \text{Excess Retention Quantity} - \text{Total Excess}.$$

For example, suppose that a critical item has a newly recomputed base stock level of 16, an annual demand of 21, and an on-hand quantity of 118. Based upon these parameters, the total excess is 102 (i.e., 118 On-hand – 16 Base Stock Level). Given that the maximum allowable retention time for a critical item is 24 months expected demand, the excess retention quantity is 42 (i.e., 21 Annual Demand * 2 years). Therefore, the total amount of returnable/disposable excess inventory is 60 (i.e., 102 Total Excess – 42 Excess Retention Quantity). If the item is a non-critical item, then the maximum allowable retention time is 18-months expected demand. Under this condition, the excess retention quantity is 32 (i.e., 21 Annual Demand * 1.5 years) and the total amount of returnable/disposable excess is 70 (i.e., 102 Total Excess – 32 Excess Retention Quantity).

[40] Marine Corps Order (1992), p. 2-3.

C. DATA ANALYSIS

1. Data Collection

The SMU provided the project group with a Retail Demand File (dated April 2007), which the project group used to collect data. First, the project group determined the overall population of the SMU's inventory, which consisted of 19,833 items valued at $37,181,832. Then, the project group reviewed the preceding 12 months and subtracted 7,211 items that had zero demand. This provided the project group with an adjusted population size of 12,622 items valued at $29,189,577. Next, the project group determined that a sample size of 984 was required in order to obtain a confidence level of ninety-five percent and a confidence interval of three. For simplicity, the project group rounded the sample size from 984 to 1,000. Based upon this calculation, the project group collected the sample from the first 1,000 items in the SMU's inventory (sorted from most to least expensive). This sample collection method enabled the project group to obtain a sample that represented 82 percent of the SMU's inventory value. Finally, the project group developed spreadsheet models to calculate the reorder quantity, reorder point, and safety level. A summary of the data collected is provided in Table 8.

	Quantity	Value
Initial population size	19,833	$37,181,832
Total items removed from population due to insufficient demand data	7,211	$7,992,254
Adjusted population size (after removing items with insufficient demand data)	12,622	$29,189,577
Sample Size (82% of total inventory value)	1000	$23,804,226

Table 8. Data Collection Summary

2. Data Analysis

a. Demand Variability

Using the previous 12 months of historical demand data, the project group found that only 279 out of the 1000 sample demand data follow a normal distribution. For these 279 items, a normal distribution was used to compute the reorder point and safety stock. For the remaining 721 sample demand data, a Poisson distribution was used to compute the reorder point and safety stock.

b. Reorder Point and Safety Level

Once the project group determined that the majority of demand data follows a Poisson distribution, the project group computed the reorder point and safety level for the sample via Microsoft Excel. The computation of the reorder point and safety level was driven by the following:

1. Daily mean demand during periods of demand
2. Lead time
3. Service level prescribed based upon criticality.

Using 12-months of historical demand data, the project group multiplied the daily mean demand during periods of demand by the lead time in order to obtain the mean demand during lead time. To obtain lead time data, the project group collected a 12-month voucher file, which provides a summary of all orders and receipts for the SMU. Lead time was calculated for demand items by subtracting the receipt date from the order date. For items that did not have lead time data readily available (due to system errors or lack replenishment demands), the project group used DLA's quoted lead time based upon the priority assigned to requisitions (provided in Table 9). Moreover, the project group estimated lead time based upon the criticality of items. For critical items, lead time was estimated at seven days. For non-critical items, lead time was estimated at sixteen days.

MILSTRIP PRIORITY
URGENCY OF NEED DESIGNATOR

Force/Activity Designator	A	B	C
I	PRIORITY DESIGNATOR 1 Conus: 3.5 Days Overseas: 8.5 - 11 Days Express*: 6.5 Days	PRIORITY DESIGNATOR 4 Special RDD Entry** Conus: 7 Days Overseas: 14 - 16 Days Other RDDS: Conus: 16 Days Overseas: 44 – 78 Days	PRIORITY DESIGNATOR 11 Special RDD Entry*** Conus: 7 Days Overseas: 14 – 16 Days Other RDDS: Conus: 16 Days Overseas: 44 – 78 Days
II	PRIORITY DESIGNATOR 2 Conus: 3.5 Days Overseas: 8.5 - 11 Days Express*: 6.5 Days	PRIORITY DESIGNATOR 5 Special RDD Entry** Conus: 7 Days Overseas: 14 - 16 Days Other RDDS: Conus: 16 Days Overseas: 44 – 78 Days	PRIORITY DESIGNATOR 12 Special RDD Entry*** Conus: 7 Days Overseas: 14 – 16 Days Other RDDS: Conus: 16 Days Overseas: 44 – 78 Days
III	PRIORITY DESIGNATOR 3 Conus: 3.5 Days Overseas: 8.5 - 11 Days Express*: 6.5 Days	PRIORITY DESIGNATOR 6 Special RDD Entry** Conus: 7 Days Overseas: 14 - 16 Days Other RDDS: Conus: 16 Days Overseas: 44 – 78 Days	PRIORITY DESIGNATOR 13 Special RDD Entry*** Conus: 7 Days Overseas: 14 – 16 Days Other RDDS: Conus: 16 Days Overseas: 44 – 78 Days
IV	PRIORITY DESIGNATOR 7 Special RDD Entry** Conus: 7 Days Overseas: 14 - 16 Days Other RDDS: Conus: 16 Days Overseas: 44 – 78 Days	PRIORITY DESIGNATOR 9 Special RDD Entry*** Conus: 7 Days Overseas: 14 – 16 Days Other RDDS: Conus: 16 Days Overseas: 44 – 78 Days	PRIORITY DESIGNATOR 14 Special RDD Entry*** Conus: 7 Days Overseas: 14 – 16 Days Other RDDS: Conus: 16 Days Overseas: 44 – 78 Days
V	PRIORITY DESIGNATOR 8 Special RDD Entry** Conus: 7 Days Overseas: 14 - 16 Days Other RDDS: Conus: 16 Days Overseas: 44 – 78 Days	PRIORITY DESIGNATOR 10 Special RDD Entry*** Conus: 7 Days Overseas: 14 – 16 Days Other RDDS: Conus: 16 Days Overseas: 44 – 78 Days	PRIORITY DESIGNATOR 15 Special RDD Entry*** Conus: 7 Days Overseas: 14 – 16 Days Other RDDS: Conus: 16 Days Overseas: 44 – 78 Days

Time includes requisition submission time and receipt take-up time.
*Applies to Overseas IPG I < 150 lbs with or RDD of 999, 777, N or E.
**Applies to Expedite Handling RDDs of N, E, 777, 555, 444 or J < 8 days.
***Applies to Expedite Handling RDDs of 555, 444 or JD < 8 days.

Table 9. Force Activity Designator Including Shipment Times (from: DLA Handbook)

Besides using the Poisson distribution, the project group also calculated the reorder point and safety level via the Days of Supply methodology. This enabled the project group to compare the two methods of computing reorder points and safety levels. This enabled the project group to show the disparities between the two methods, which provide insight as to why inventory levels are often excessive in some areas, while deficient in others. Figure 17 shows the disparity between the Poisson distribution and the Days of Supply model's calculations of the reorder points. Based upon a sample of 591 items that met the current Marine Corps' stockage criteria,[41] the Poisson method computed 387 reorder points that were higher than the Days of Supply model's computation. Additionally, the Poisson method computed 144 reorder points that were lower than the Days of Supply model's computation.

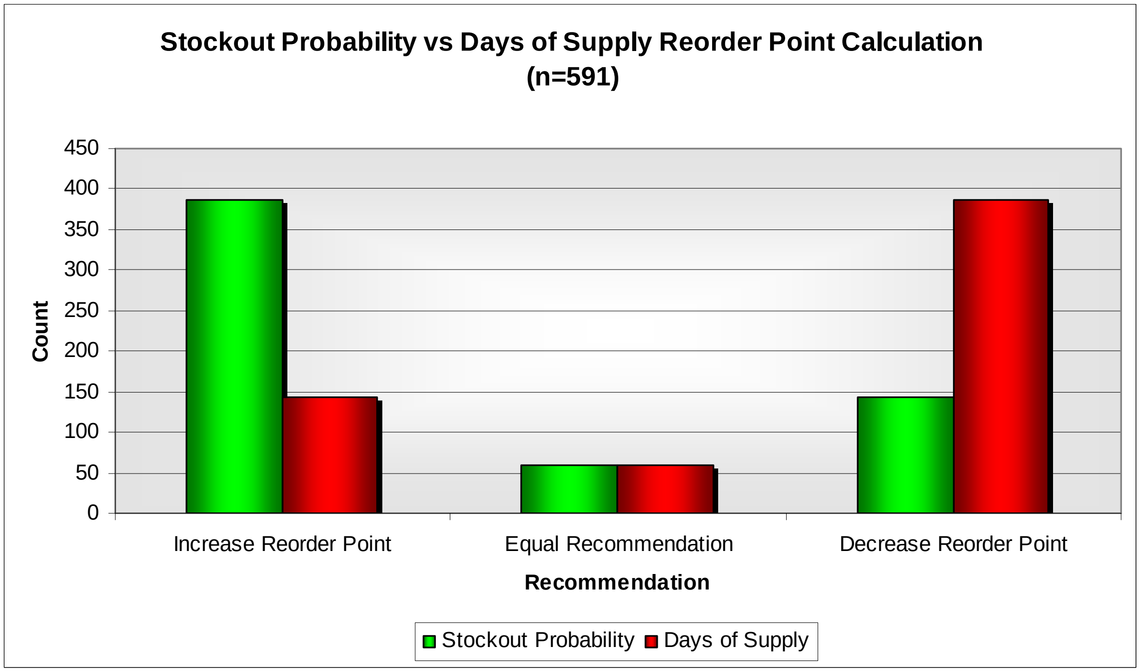

Figure 17. Stockout Probability versus Days of Supply Reorder Point

There are two reasons why the Days of Supply model prescribes reorder points that are too high or too low. The first reason is that the Days of Supply model averages down demand by averaging periods with demand with periods without demand. By failing to distinguish between periods with and without demand, the Days of Supply model recommends inventory levels that are too low. The second reason is that the Days of Supply model generalizes demand data by chunking it into categories, which consist of lead time and demand frequency. Table 10 provides an example of how the Days of Supply model oversimplifies demand data by lead time and demand frequency. Moreover, the Days of Supply model is indifferent to individual demand items in its computation of the reorder point and safety level, which are prescribed in increments of

[41] "Three recurring demands (issues) in 12 months are required to stock an item if the item is combat essential; e.g., Combat Essentiality Code (CEC) is 5 or 6. Six recurring demands (issues) in 12 months are required to stock an item if it is not combat essential." Marine Corps Order (1992), p. 1-7.

30 days. Consequently, the Days of Supply model computes reorder points and safety levels that are either too high or too low.

CWT	MONTHS W/HITS	RQMT CODE	RO DAYS	ROP DAYS	RO FORMULA	ROP FORMULA
46-50 DAYS	>0<=5	3JJC	115	65	3.83	2.16
46-50 DAYS	>5<=9	3KJC	120	65	4	2.16
46-50 DAYS	>9	3LJC	125	65	4.16	2.16

Table 10. Days of Supply Model Classification

c. Reorder Quantity

Once the project group calculated the reorder point and safety level, a stockout probability method was used to determine the reorder quantity. Specifically, the reorder quantity was based on monthly mean demand during periods with demand. Collectively, the reorder quantity, reorder point, and safety level comprise the base stock level. Figure 18 shows the disparity between the stockout probability and Days of Supply calculations of the base stock level. Based upon a sample of 591 items that met the current Marine Corps' stockage criteria,[42] the Poisson method computed 440 base stock levels that were higher than the Days of Supply model's computation. Additionally, the Poisson method computed 118 base stock levels that were lower than the Days of Supply model's computation.

42 "Three recurring demands (issues) in 12 months are required to stock an item if the item is combat essential; e.g., Combat Essentiality Code (CEC) is 5 or 6. Six recurring demands (issues) in 12 months are required to stock an item if it is not combat essential." Marine Corps Order (1992), p. 1-7.

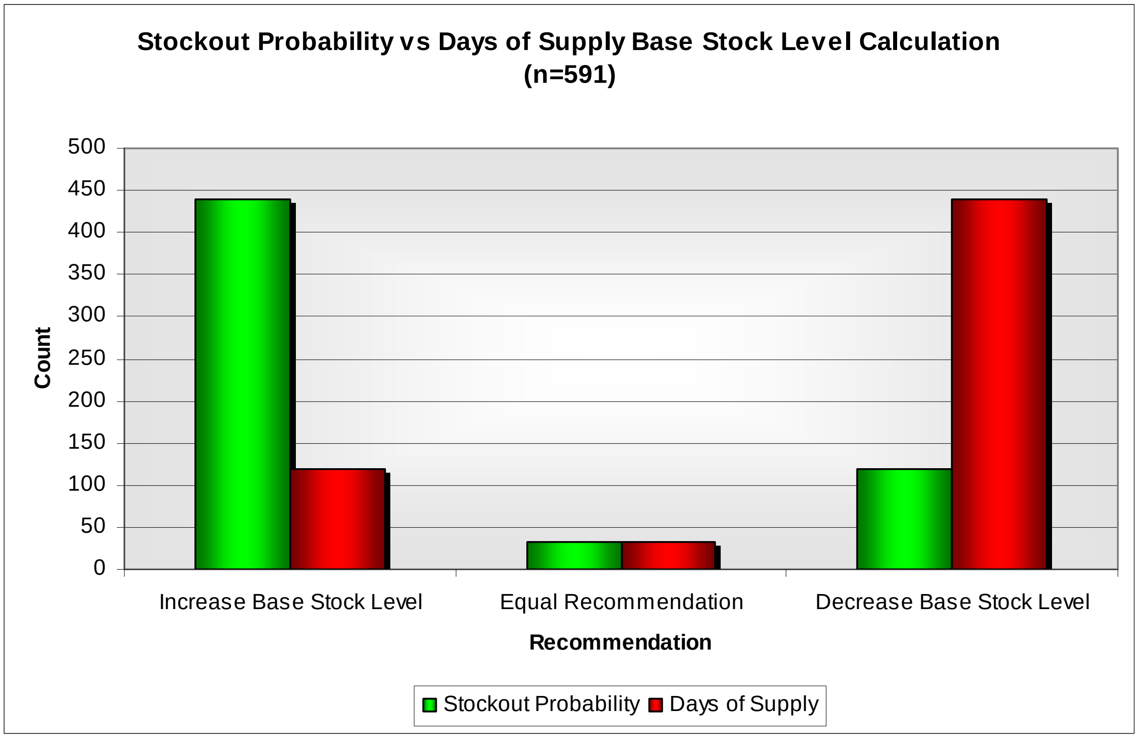

Figure 18. Stockout Probability versus Days of Supply Base Stock Level

d. Stockage Criteria

Once the project group computed the reorder quantities, reorder points, and safety levels, the project group applied and contrasted four different stockage criteria to the current Marine Corps' stockage criterion. Three of the four criteria applied were the dollar-banding criteria developed by the RAND Corporation, which included item attainability and classification (i.e., type of item). The fourth criterion was developed by the project group, which modified the existing Marine Corps' stockage criterion by incorporating item criticality, item classification, item attainability, and demand frequency into the preliminary stockage decision (see Table 11). Rather than using "dollar-banding" as a stockage selection tool, the project group used "dollar-banding" to prescribe the desired service levels for items selected in the preliminary stockage decision (see Table 12, Table 13, and Figure 19). In short, the project group developed a comprehensive decision tool for stocking item (critical and non-critical), while eliminating unnecessary items from the inventory that are typically items that are unattainable through the supply system, reparable items, or other than repair part items (e.g., clothing items). Lastly, this methodology improves the current Marine Corps' stockage criterion by including item attainability and classification in the inventory decision as opposed to just demand frequency and criticality.

	Critical	Non-Critical
Total Demands per Year	>= 3	>= 6
Combat Essentiality Code	5 or 6	2, 3, or 4
Acquisition Advice Code	A, B, C, D, E, G, or H	A, B, C, D, E, G, or H
Material Identification Code	B, D, K, or O	B, D, K, or O
Recoverability Code	A or Z	A or Z

Table 11. Proposed Marine Corps' Stockage Criterion[43]

Critical Item						
Item Cost	x < $100		$100 =< x< $500		$500 <= x	
Demands Per Year	Service Level	σ	Service Level	σ	Service Level	σ
x <= 30	99.0097%	2.33	96.9946%	1.88	95.0529%	1.65
30 < x <= 60	99.4252%	2.53	98.2920%	2.12	97.1875%	1.91
60 < x <= 90	99.6780%	2.72	99.0773%	2.36	98.4928%	2.17
90 < x <= 120	99.8260%	2.92	99.5264%	2.59	99.2394%	2.43
120 < x <= 150	99.9093%	3.12	99.7692%	2.83	99.6388%	2.69
150 < x <= 180	99.9544%	3.32	99.8933%	3.07	99.8388%	2.95
180 < x <= 210	99.9779%	3.51	99.9532%	3.31	99.9324%	3.20
210 < x <= 240	99.9897%	3.71	99.9805%	3.55	99.9734%	3.46
240 < x <= 270	99.9954%	3.91	99.9923%	3.79	99.9901%	3.72
270 < x <= 300	99.9980%	4.11	99.9971%	4.02	99.9966%	3.98
300 < x <= 330	99.9992%	4.30	99.9990%	4.26	99.9989%	4.24
330 < x	99.9997%	4.50	99.9997%	4.50	99.9997%	4.50

Table 12. Dollar-banded Service Levels for Critical Items

[43] Detailed descriptions of Combat Essentiality Codes, Materiel Identification Codes, Acquisition Advice Codes, and Recoverability Codes are provided in Appendixes A thru D.

Non-critical Item						
Item Cost	x < $100		$100 =< x< $500		$500 <= x	
Demands Per Year	Service Level	σ	Service Level	σ	Service Level	σ
x <= 30	95.9941%	1.75	89.9727%	1.28	84.8495%	1.03
30 < x <= 60	97.7250%	2.00	94.2109%	1.57	91.0761%	1.35
60 < x <= 90	98.7776%	2.25	96.8941%	1.87	95.1634%	1.66
90 < x <= 120	99.3790%	2.50	98.4543%	2.16	97.5943%	1.98
120 < x <= 150	99.7020%	2.75	99.2875%	2.45	98.9042%	2.29
150 < x <= 180	99.8650%	3.00	99.6962%	2.74	99.5437%	2.61
180 < x <= 210	99.9423%	3.25	99.8803%	3.04	99.8265%	2.92
210 < x <= 240	99.9767%	3.50	99.9564%	3.33	99.9399%	3.24
240 < x <= 270	99.9912%	3.75	99.9854%	3.62	99.9810%	3.55
270 < x <= 300	99.9968%	4.00	99.9955%	3.91	99.9945%	3.87
300 < x <= 330	99.9989%	4.25	99.9987%	4.21	99.9986%	4.18
330 < x	99.9997%	4.50	99.9997%	4.50	99.9997%	4.50

Table 13. Dollar-banded Service Levels for Non-critical Items

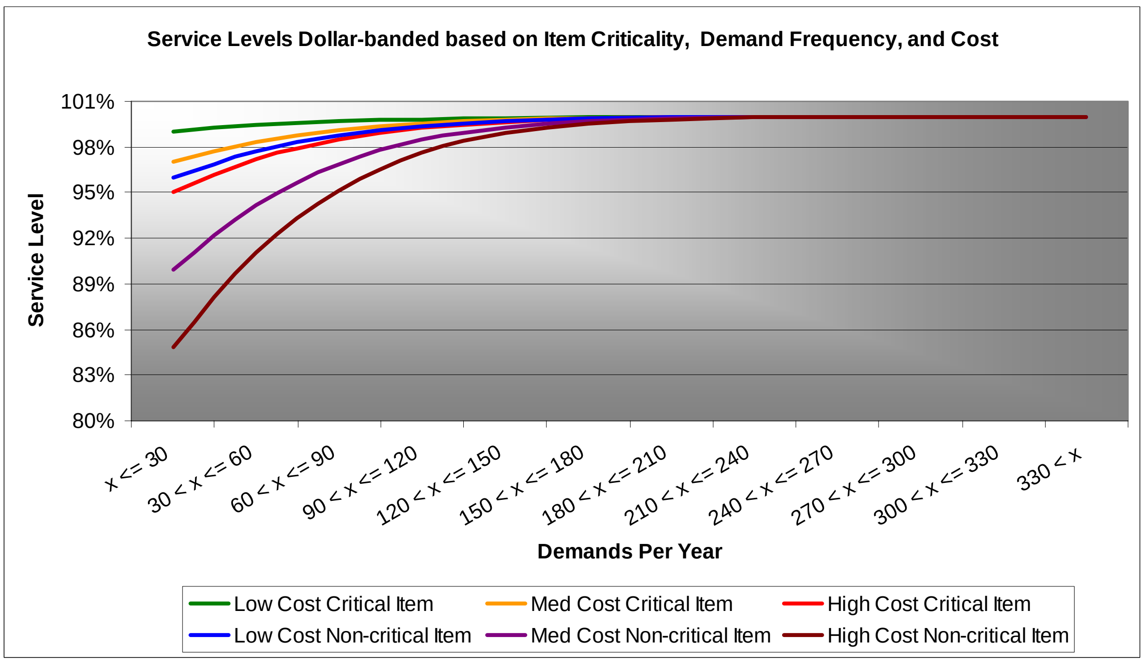

Figure 19. Service Levels Dollar-banded based on Item Criticality, Demand, and Cost

Figure 20 provides a summary of the inventory level and excess calculations per stockage criteria used. In general, all inventory methods suggest that approximately $6.9 – $7.1 million worth of inventory is infeasible excess and should be either returned to the supplier for partial credit or sent to disposal. This means that based upon current and projected consumption rates, it is not economical to maintain this level of inventory. Conversely, approximately \$8.1 – \$12.6 million worth of excess inventory is economical to maintain based upon current and projected consumption rates. The magnitude of the feasible excess is driven by the base stock level prescribed by each inventory method.

The base scenario (i.e., current Marine Corps' stockage criterion), based solely on demand frequency and item criticality, prescribed a base stock level of \$8.9 million. Conversely, the other stockage criteria, which take account of item attainability and classification, suggested base stock levels ranging from \$4.1 – \$6.3 million. The three stockage criteria (i.e., Simple, Medium, and Complicated Demand and Cost Rules) with the lowest base stock levels were based solely on dollar-banding with no consideration given to item criticality. These base stock levels ranged from \$4.1 – \$4.9 million. In reality, these three scenarios are not practical for the SMU, since no consideration is given to item criticality in inventory stockage decision. Therefore, the fourth scenario (i.e., proposed Marine Corps' stockage criterion) is the most favorable, since it is based on item criticality, item attainability, item classification, demand frequency, and dollar-banding. This scenario prescribed a base stock level of \$5.8 million.

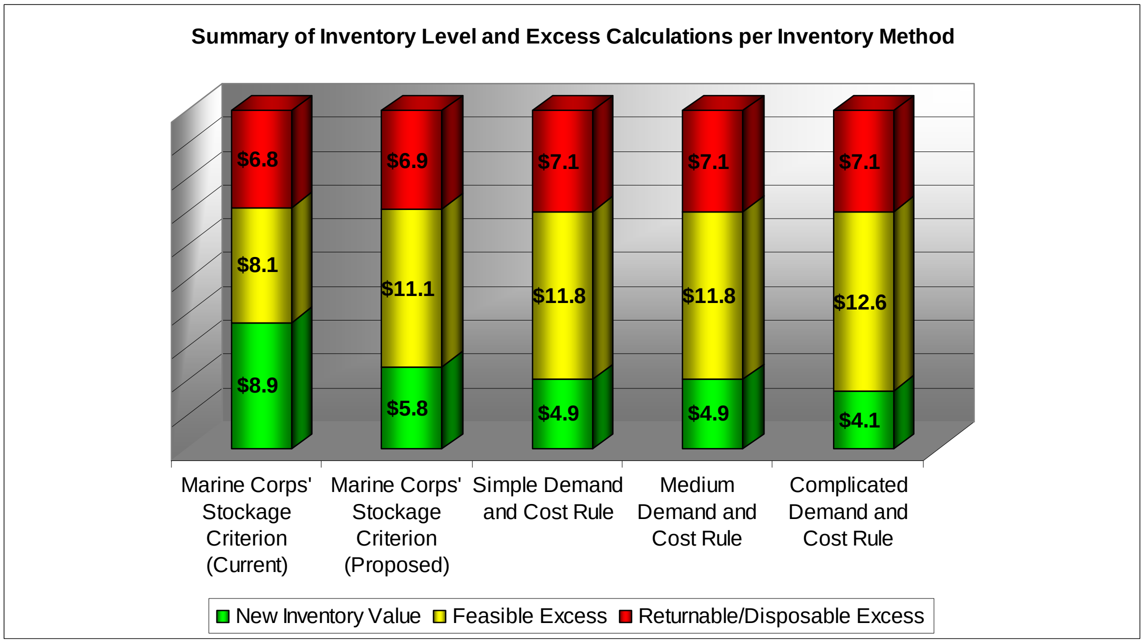

Figure 20. Summary of Inventory Level and Excess Calculations per Inventory Method

D. INVENTORY MANAGEMENT SIMULATION

1. Simulation Overview

After the project group calculated the reorder quantities, reorder points, and safety levels via the two inventory methods (i.e., stockout probability and Days of Supply), the project group developed an inventory management simulation in Arena.[44] The purpose of the simulation was to test the validity of the stockout probability model and compare it to the current inventory and the Days of Supply model in terms of average stockouts and average inventory value (i.e., on hand + on order). Six scenarios were developed and tested via the simulation. Descriptions of each scenario are as follows:

1. The first scenario consisted of the original sample of 1,000 items that comprised 82 percent of the population inventory. This scenario was the base scenario as inventory levels were tested in its present condition.

2. The second scenario consisted of a sample of 591 items that met the Marine Corps' current stockage criterion. Specifically, inventory levels were decided on the basis

44 Arena is a simulation program marketed by the Rockwell software company.

of demand frequency and criticality, with no consideration given to item attainability, item classification, or cost. Moreover, these items were computed and simulated via DOS methodology.

3. The third scenario consisted of a sample of 411 items that met the proposed Marine Corps' current stockage criterion, which is based on item criticality, item attainability, item classification, demand frequency, and dollar-banding. Unlike the second scenario, these items were computed and simulated via the stockout probability methodology. Moreover, service levels were prescribed based upon the item criticality, demand frequency, and cost.

4. The fourth scenario consisted of a sample of 293 items that met the simple demand and cost rule criterion (established by RAND Corporation). Additionally, item attainability and item classification were incorporated into the inventory stockage decision. Unlike the third scenario, service levels for items were prescribed solely based on cost as opposed to criticality.

5. The fourth scenario consisted of a sample of 300 items that met the medium demand and cost rule criterion (established by RAND Corporation). Additionally, item attainability and item classification were incorporated into the inventory stockage decision. Unlike the third scenario, service levels for items were prescribed solely based on cost as opposed to criticality.

6. The fourth scenario consisted of a sample of 280 items that met the complicated demand and cost rule criterion (established by RAND Corporation). Additionally, item attainability and item classification were incorporated into the inventory stockage decision. Unlike the third scenario, service levels for items were prescribed solely based on cost as opposed to criticality.

Each scenario simulated reorder quantities, reorder points, and safety levels by incorporating demand and lead time variability, which was based upon actual historical demand and lead time data. Each scenario was simulated for 1,000 replications, which enabled the project group to obtain an average within close proximity to the true value. A screenshot of the inventory management simulation is provided in Figure 21.

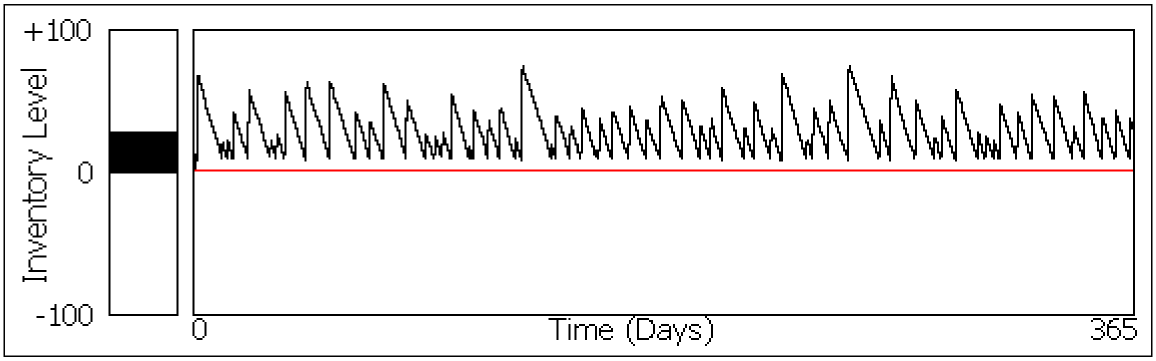

Figure 21. Inventory Management Simulation Screenshot

To simulate demand variability, the project group dissected the historical demand data into three categories. The first category consisted of months in which there was zero demand. Specifically, this category represents a percentage of the year in which there will be no demand. The second category consists of the annual spike in demand or the month with the highest demand, which represents 8 percent of the annual demand. Since spikes in demand are relatively infrequent, it is necessary to isolate these incidents when testing reorder quantities, reorder points, and safety levels. Otherwise, the results will be significantly skewed. The final category consists of demand that fluctuates between the lowest demand quantity higher than zero and the highest demand quantity below the spike in demand. This category is tested as a uniform distribution whereby there is a minimum quantity and a maximum quantity. Collectively, these categories comprise a custom discrete probability distribution whereby a percentage of the annual demand will either be zero, a spike, or fluctuate around mean demand. An example of this distribution is illustrated in Figure 22.

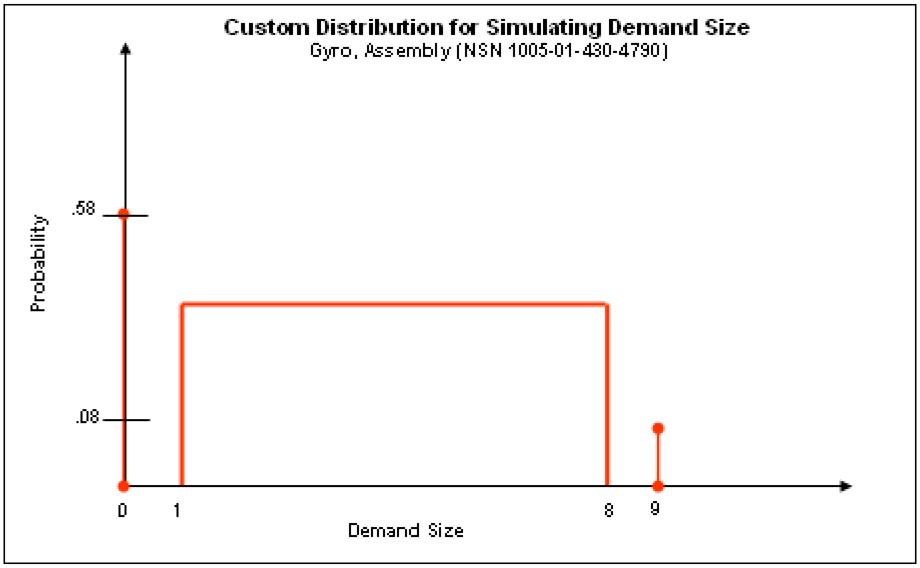

Figure 22. Custom Distribution for Simulating Demand Size

To simulate lead time variability, the project group used a combination of historical lead time data and DLA quoted lead times. Lead time was simulated via a triangular distribution in which there was a minimum, maximum, and an average. The maximum lead time was developed by adding a value of 12 days to the mean lead time, which consists of the average marginal value between each of DLA's quoted lead times. This is based upon the different requisition priority categories commonly referred to as Force Activity Designators. The minimum value was one in all instances, since DLA has the capability of expediting shipments.

2. Simulation Results

Upon conclusion of the simulation, the project group recorded the results and contrasted the results of each scenario to the current inventory levels in terms of average stockouts, fill rates, average inventory value, item availability improvements, and inventory reductions. As indicated in Table 14, Figure 23, and Figure 24, the current inventory simulated an average of 171.31 stockouts per year over 1,000 replications (i.e., 171,310 total stockouts ÷ 1,000 replications or 1,000 simulated years). Moreover, the simulated average inventory value per year (i.e., On-hand + On-order) was $68.8 million. This indicates that the current inventory levels are in excess of expected demand in some areas, while deficient with respect to expected demand in others.

Unlike the simulation of the current inventory levels, all other methods for selecting items for stockage and prescribing the appropriate inventory levels demonstrated significant improvements. Specifically, simulated average stockouts per year were reduced by up to 99.98 percent. Moreover, the simulated average inventory value was simultaneously reduced by up to 75.44 percent. This translates to a significant improvement in customer service coupled with a considerable reduction in needless inventory. The simulation results that demonstrated the greatest improvement in availability and inventory reduction were the dollar-banding scenarios based solely on cost. Although impressive, this methodology is not feasible, since no consideration is given towards the criticality of the item. Therefore, the most practical methodology for the SMU is the proposed Marine Corps' stockage criterion based upon item criticality, stockout probability, and dollar-banding. This proposed criterion also incorporates item attainability, item classification, demand frequency, and cost. Moreover, this criterion demonstrated a 99.98-percent improvement in item availability, while reducing inventory levels by 68.33 percent.

Sample Description	Items Meeting Criteria	Average Stockouts	Fill Rate Spread	Average Inventory Value	Availability Improvement	Inventory Reduction
Current Inventory (Unchanged)	1000	171.31	91.28 - 100%	$68,779,704	-	-
Marine Corps' stockage criteria (Current)	591	7.44	95.75 - 100%	$37,931,567	95.66%	44.85%
Marine Corps' stockage criteria (Proposed)	411	0.06	99.98 - 100%	$21,785,191	99.96%	68.33%
Simple Demand & Cost Rule	293	0.04	99.98 - 100%	$15,409,671	99.98%	77.60%
Medium Demand & Cost Rule	300	0.04	99.98 - 100%	$18,923,690	99.98%	72.49%
Complicated Demand & Cost Rule	280	0.05	99.98 - 100%	$16,889,612	99.97%	75.44%

Table 14. Inventory Management Simulation Results

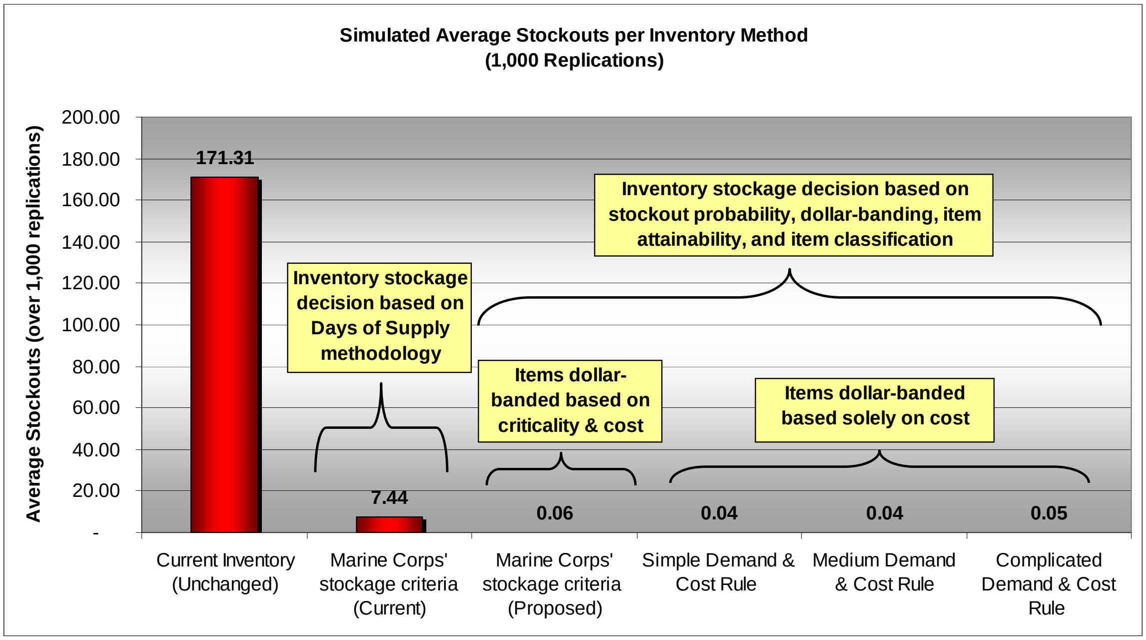

Figure 23. Simulated Average Stockouts per Inventory Method

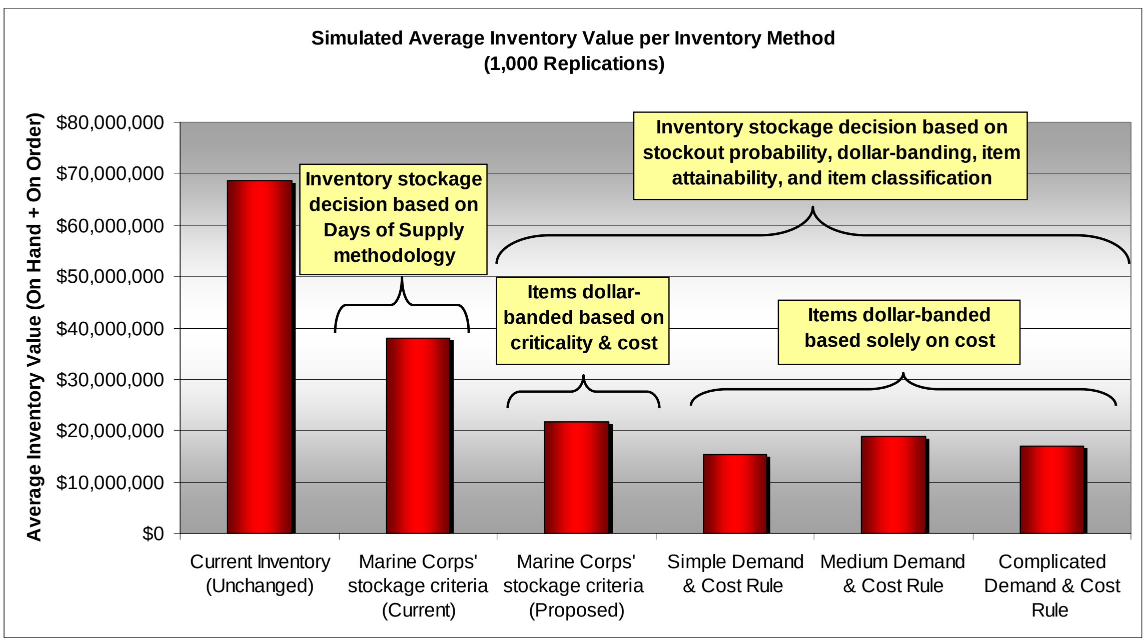

Figure 24. Simulated Average Inventory Value per Inventory Method

E. CONCLUSION

In this chapter, the project group discussed two methods for calculating the base stock level, reorder point, and safety level. The first method is the EOQ method, which incorporates inventory holding and ordering costs. This method assumes that demand is relatively constant and seeks to minimize total inventory cost. The second method is the stockout probability method, which incorporates demand variability and excludes costs. Based upon the shortcomings of the Days of Supply methodology and the magnitude of demand variability, the project group concluded that stockout probability is the most appropriate method for the SMU to use to establish base stock levels. For determining reorder points and safety levels, the SMU should use either a Poisson distribution, normal approximation to Poisson, or a normal distribution (depending on the magnitude of demand variability). This will enable the SMU to specify the desired service level for particular demand items, such as critical or non-critical items. Moreover, the SMU should always include all periods with demand and assume that demand is not constant when computing daily mean demand during lead time. This will ensure that reorder points and safety levels are not too low, which results from demand being averaged down by eliminating the high and low months of demand.

In this chapter, the project group used and tested the RAND Corporation's "dollar-banding" method for stocking items based upon demand frequency and cost. Although this methodology is practical from a cost and usage perspective, the dollar-banding method is not feasible for the SMU to use as a determinant for stocking items. The reason being is that item criticality is excluded from stockage decision. Therefore, the project group built upon the dollar-banding methodology by using item criticality, item classification, item attainability, and demand frequency as the baseline for stocking an item. In addition, the project used dollar-banding to prescribe the desired service level based upon demand frequency and cost. Collectively, the project group developed a comprehensive decision tool that will enable the SMU to make better inventory stockage decisions that efficiently balance readiness with cost.

To substantiate the project group's claim that the stockout probability method is a feasible alternative to Days of Supply model, the project group tested the stockout probability model's calculations of the reorder quantity, reorder point, and safety level via an inventory management simulation that incorporates demand and lead time variability. The simulation results indicate that the SMU should base inventory stockage decisions on a stockout probability and dollar-banding strategy that incorporates item criticality, item attainability, item classification, demand frequency, and cost. This will enable the SMU to improve item availability by approximately 99.98 percent, while reducing inventory levels by roughly 68.33 percent. This is consistent with results that have been achieved in the commercial sector. For example, Hewlett Packard's Microwave Instruments Division (MID) had traditionally experienced frequent stockouts and difficulty determining appropriate inventory levels. For that reason, MID implemented a statistical inventory method, which established inventory levels based on the probability of stockout.

> Within three weeks of implementing the new approach to inventory control, MID experienced remarkable availability improvements, with no increase in inventory investment. Backorders vanished. Shipments were unconstrained by part availability, resulting in shorter lead times to customers and improved delivery performance.[45]

In deciding whether to stock, retain, or dispose an item, inventory managers often consider only the criticality of the item without regard to the probability of demand or cost. Subsequently, inventory managers often select items with little usage for stockage, retain the items for prolonged periods of time (despite insufficient demand), and dispose of the item in a piecemeal fashion. Although there are systems in place for disposing excess inventory, such as the Material Returns Program (MRP) and the Defense Reutilization and Marketing Service (DRMS), inventory managers often lack managerial controls that will ensure that items that lack sufficient demand are either returned to the supplier for partial credit or made available to other end users by placing the item back into the supply system. Specifically, inventory reviews and excess reporting often do not coincide. This causes the identification, reporting, and subsequent disposal of excess inventory to be a fairly lengthy process. In addition, a high personnel turnover in terms of inventory managers only adds to this complexity.

[45] ORMS Today (1999).

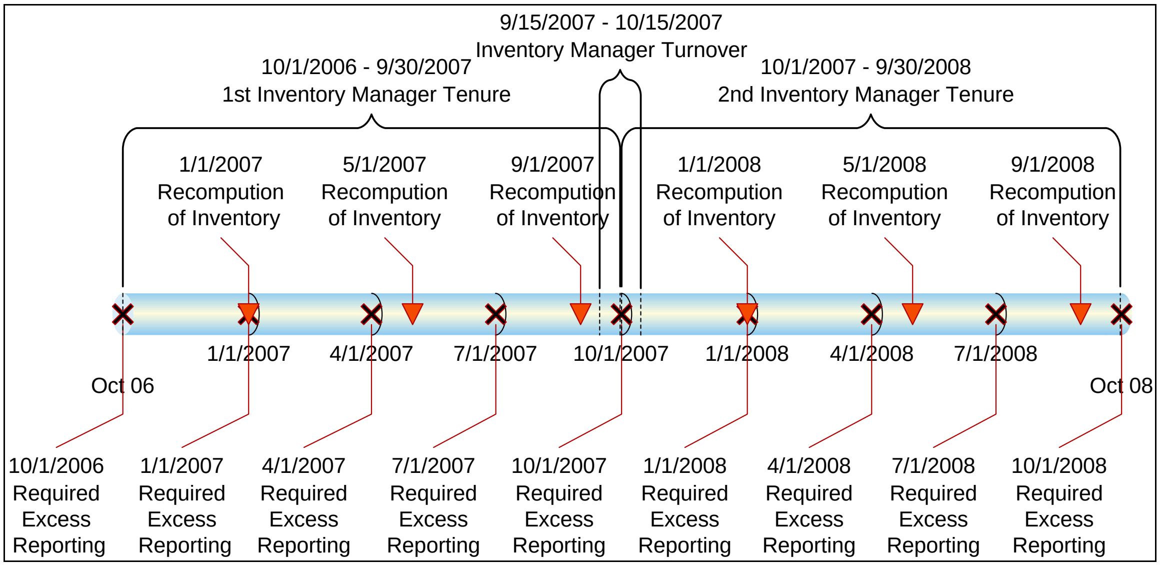

Figure 25. Inventory Reviews, Excess Reporting, and Inventory Manager Turnover

Figure 25 provides a two-year timeline, which illustrates a typical SMU's schedule for inventory recomputations, excess reporting, and inventory manager turnover. It is evident that there is an inconsistency with regards to when inventory levels are recomputed and when excess inventory is reported. Specifically, economic retention quantities should be calculated when inventory levels are recalculated. The reason being is that the economic retention quantity can change dramatically between inventory reconciliations due to continual fluctuations in demand. Therefore, the SMU should always ensure that economic retention quantities and excess reporting/disposal coincide with inventory recomputations.

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IV. OPERATIONAL AVAILABILITY

A. BACKGROUND

> DoD has wasted billions of dollars on excess supplies because inherent in DoD's culture is the belief that it is better to overbuy items than to manage with just the amount of stock needed. If DoD had used effective inventory management and control techniques and modern commercial inventory management practices, it would have had lower inventory levels and avoided the burden and expense of storing excess inventory. DoD has clearly had some success in addressing its inventory management problems, but much remains to be done.[46]

At all levels of DoD, culture is by far the largest contributor to excess inventory. Particularly, the reluctance to acknowledge problematic inventory management practices and implement change prevents DoD from reducing inventory, while simultaneously improving readiness. Several businesses in the commercial sector have clearly demonstrated that efficient management of the supply chain is a catalyst for eliminating waste. Despite this fact, inventory managers throughout DoD continue to stockpile inventories in aspiration that this will lead to higher readiness levels. Moreover, as inventory managers operate independently and seek to optimize their own readiness levels via inventory accumulation, DoD continues to incur substantial amounts of excess on aggregate.

> DoD's current mission, organizational structure, evaluation, and reward systems, promote excess inventory. Focusing on material availability *at any cost* without regard for high inventory levels leads to conflicting objectives. DoD must review all the fundamental factors of inefficiency including organizational structure, evaluation and incentive/reward systems.[47]

From the Defense Budget Cycle down to excess inventory reporting and disposal criteria, there are several incentives for inventory managers not to reduce excess inventory. At the macro-level, fewer inventories translates to budget reductions, since inventory managers are able to significantly reduce the costs of ordering and holding

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[46] GAO Report (1997).

[47] Kang (1998), p.1.

inventory. In the commercial sector, this is completely feasible and even encouraged since efforts to reduce inventory add to the bottom-line (or profitability). However, since DoD is not-for-profit, there is no incentive to reduce operational expenses, especially since there are four rules that govern budget execution:

1. Spend it all.
2. Do not overspend.
3. Spend it on the right stuff.
4. Do not get confused.[48]

These rules are firmly established in Title 31 policy documents. The ability to follow these rules could potentially be the difference between career progression and career termination. Specifically, budget managers (to include inventory managers) are held responsible for what they do or do not spend, based upon the amount of funding that was requested.

> Most managers within DoD know that not obligating money within the fiscal year is a cardinal sin, an automatic budget cut in the current year, a probable cut in the next year, and a potential indictment of other programs of that manager. The logic is that someone fought to get those funds into the Program Objective Memorandum (POM), the defense budget, the proposed appropriation bill, and through Congress, and now they are not being obligated.[49]

Since the inability to expend resources is considered taboo, there is little incentive to drive down operational expenses. Therefore, budget managers tend to underreport excess, while overstating requirements. As a result, inventory managers are often forced to spend surplus resources at the end of each fiscal year, which in turn promotes excess. This phenomenon is generally referred to in business as the "Hockey-Stick Effect," whereby spending volume tends to pick up near the end of the fiscal year. Figure 26 provides an illustration of the "Hockey-Stick Effect" on annual basis, which provides insight as to how excess inventory accumulates as a result of spend-out waste. Moreover, Figure 27 provides an illustration of DoD's "Hockey Stick Effect" based upon monthly

[48] McCaffery and Jones (2006), pp.227-231.

[49] Ibid., p. 80.

obligation Operation and Maintenance (O&M) rates from 1977-1990, which substantiates the argument that excess inventory can be largely attributed to DoD's budget culture.

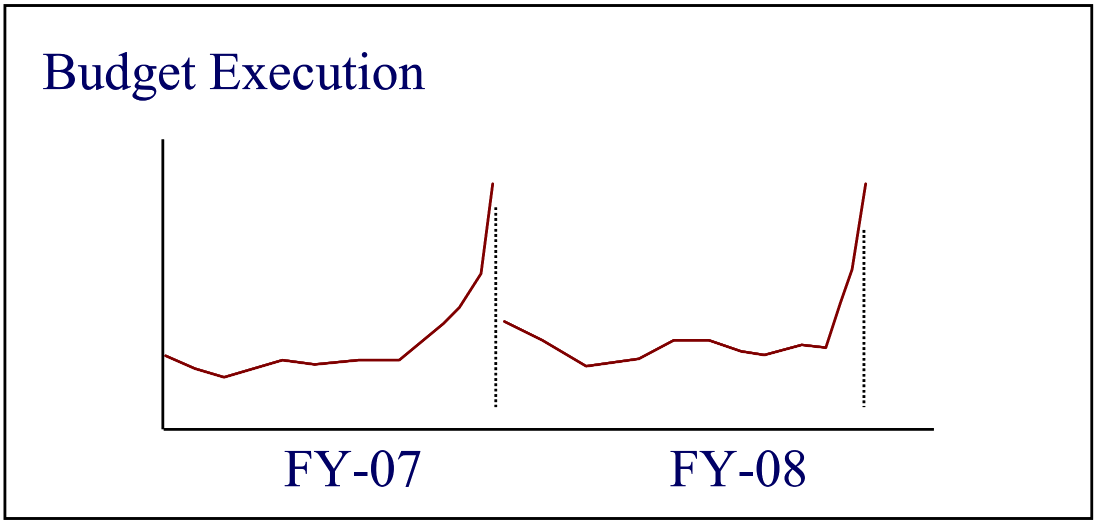

Figure 26. Hockey Stick Effect Illustration (from Geraldo Ferrer)

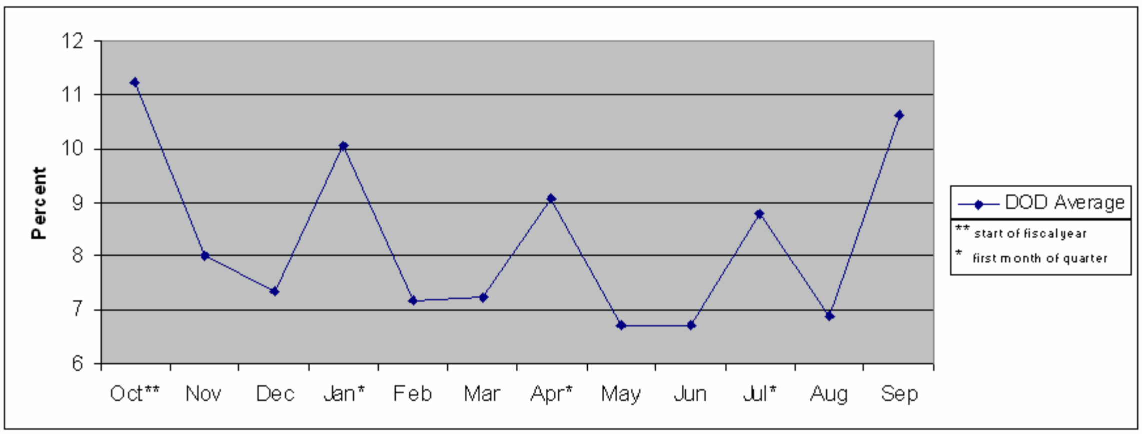

Figure 27. DoD Monthly O&M Obligation Rates (1977-1990)[50]

At the micro-level, excess inventory can be largely attributed to outdated inventory management practices and systems coupled with a natural distrust in the supply chain. Unlike the commercial sector, DoD's inventory management practices and systems at the wholesale level have failed to substantially evolve. Moreover, inventory management policy manuals have been continually neglected, yet unquestioned. Additionally, the complexity of inventory management systems in conjunction with high

[50] Kozar (1993), p. 135.

personnel turnover results in a shortage of resident inventory management experts. As a result, inventory managers often rely on questionable rules of thumb to calculate inventory levels as opposed to legitimate statistical process controls. This explains to a certain extent why inventory managers retain unnecessary inventory, while having tremendous difficulty improving readiness. This leads to the concept of Operational Availability.

B. OPERATIONAL AVAILABILITY

> The Operational Availability (Ao) of a system is the probability that the system is capable of performing its specified function when called for at a random point in time. It is Navy policy that Ao is the primary measure of material readiness for weapon systems and equipment. It is the quantitative link between readiness objectives and supportability. Operational Availability is simply
>
> $$\text{Ao} = \frac{MTBM}{MTBM + MDT}$$
>
> where
> MTBM = Mean Time between Maintenance (System Uptime)
> MDT = Maintenance Down Time (System Downtime). [51]
>
> MTBM is measurement of system reliability whereas MDT is the total elapsed time required to repair and restore a system to full operating status. MDT consists of Mean Active Maintenance Time ($\bar{M}$) and Mean Logistics Delay Time (MLDT). MLDT is the maintenance downtime that is expended as a result of logistics delays including transportation, Mean Supply Response Time (MSRT), Mean Administrative Delay Time (MADT), and Mean Outside Assistance Delay Time (MOADT). MSRT is the average portion of downtime awaiting receipt of spare components. MSRT is usually the single greatest driver in MLDT.[52]

Since MSRT has the greatest effect on MLDT, the project group decided to focus on various methods for reducing the MSRT, such as time-series forecasting, probabilistic methods for computing inventory levels, stockage criteria, and information sharing.

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[51] Office of the Chief of Naval Operations Instruction (2003), pp. 60-64.

[52] Ibid.

These methods relate directly to consumable inventory management at the SMU. However, a holistic approach to decreasing MSRT would also include methods for improving the functionality and responsiveness of the supply chain and distribution network. At the micro-level, this translates to the implementation of better business practices at the warehouse and distribution level, such as Lean Six Sigma, modeling, and simulation. This involves the identification and elimination of non-value added activities that result in waste and impair quality. At the macro-level, this translates to total asset visibility, information sharing, and coordinated distribution activities. In short, a holistic approach is essential to improving MSRT, which will ultimately improve operational availability and customer satisfaction.

C. AN INTEGRATED APPROACH FOR DECREASING MEAN SUPPLY RESPONSE TIME

In general, there are two basic methods for effectively reducing MDT. The first method is to decrease mean active maintenance time by improving the efficiency of maintenance actions. For instance, the maintenance personnel at Fleet Readiness Center (FRC) Lemoore have used Lean Six Sigma techniques to identify and eliminate non-value added activities that produce waste and impair the quality of maintenance actions. Additionally, FRC Lemoore has applied ergonomic concepts to maintenance facilities, such as work station placement; tool organization, storage, and retrieval; and independent assembly line configuration. This has significantly reduced the flow of materials and subsequent rework. Consequently, FRC Lemoore has been able to drastically reduce maintenance turn-around time, which has notably improved operational availability.

The second method for reducing MDT is to reduce MSRT by applying a combination of value-added activities, such as information sharing, time-series forecasting, probabilistic inventory computation, efficient warehouse and distribution management, and effective process management (see Figure 28). Case in point, Wal*Mart's investment and successful implementation of Electronic Data Interchange (EDI) [53] has significantly reduced demand variability via information sharing.

[53] Wikipedia (2007a).

Consequently, Wal*Mart has improved forecast accuracy, which has led to fewer inventories, faster replenishment turn-around times, and competitive operational expenses. While Wal*Mart's investment into EDI has enabled Wal*Mart to streamline its supply chain and distribution network, it is not a simple, inexpensive solution for the military. In reality, the implementation of EDI is a long-term supply chain investment, which is both costly and complicated. Therefore, a less expensive and more practical method to share information is to develop a recurrent customer-supplier dialogue via normal communication modes (i.e., email, telephone, video teleconferencing, and etc.) and commercial-off-the-shelf (COTS) software (i.e., Microsoft Excel, Access, PowerPoint, etc.). Additionally, by developing an integrated relationship with maintenance personnel, an inventory manager can obtain firsthand insight as to which demand items are the most critical to readiness. This dialogue is important, especially since the criticality of certain items can only be determined via expert opinion rather than simply demand data. Overall, the sharing of demand-related information (i.e., aggregate demand forecasts and current inventory levels) is critical to reducing demand variability and improving MSRT.

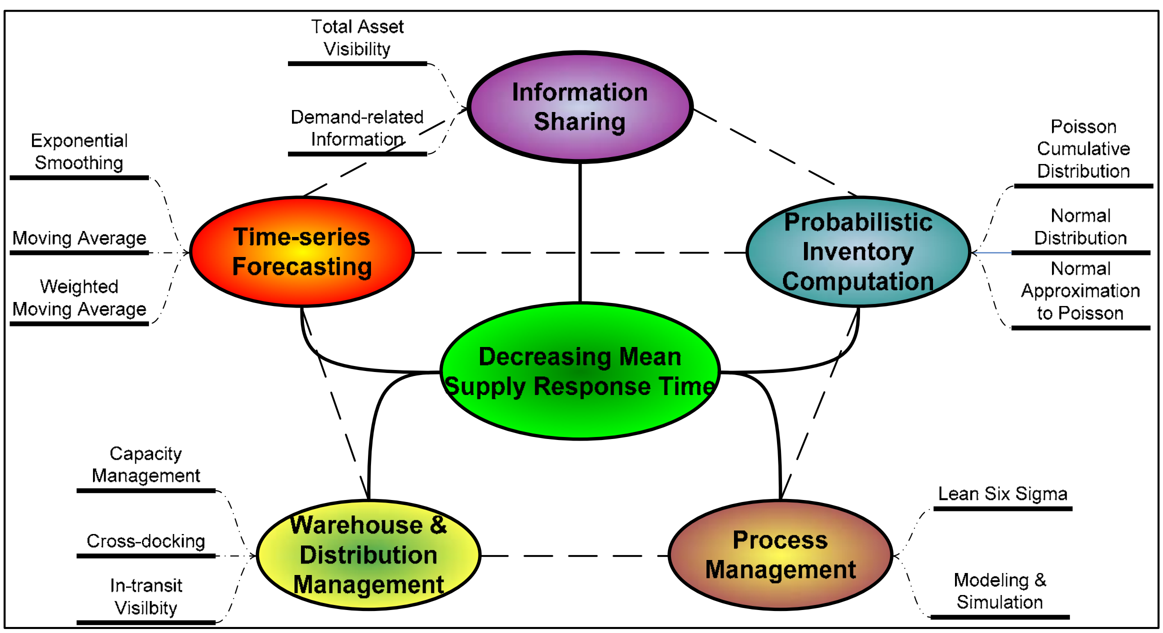

Figure 28. An Integrated Approach for Decreasing Mean Supply Response Time

Besides information sharing, MSRT can be greatly reduced by using probabilistic methods to compute inventory levels as opposed to deterministic methods. Particularly, an inventory manager should always compute inventory levels based on the premise that demand is variable as opposed to constant. Accordingly, inventory levels should be computed based upon the probability of stockout via the normal distribution, Poisson distribution, or the normal approximation to Poisson methods. These methods enable an inventory manager to account for demand variability in the computation of inventory levels. Moreover, the inventory manager can use these probabilistic methods to prescribe appropriate service levels that account for demand frequency, item criticality, and cost. This will enable the inventory manager to simultaneously improve readiness and minimize inventory expenses.

Besides using probabilistic methods to calculate inventory levels, MSRT can be reduced by improving the efficiency of warehouse and distribution operations. For instance, a warehouse typically receives replenishment inventory, places the inventory in a warehouse location, and adds the inventory to the property records. The inventory remains at this location until either there is a demand for the item or the item is removed by storage personnel, because the item is no longer feasible to maintain in the inventory. In some instances, there may be a preexisting demand for a newly received item that is not realized until after the item has been stored. Consequently, this inventory has to be retaken off the storage location, repacked, and shipped to the customer. This translates to the double-handling of inventory.

Unless warehouse personnel specifically track and document the movement of inventory throughout the warehouse, the double-handling of inventory is not always evident. Double-handling of inventory is a non-value added activity that translates to an increased MSRT, which ultimately impairs operational availability. Therefore, warehouse and distribution managers should strive to eliminate the double-handling of inventory. This can be accomplished by means of cross-docking and In-transit visibility (ITV) technologies. Cross-docking and ITV enables a warehouse or distribution manager to analyze inbound shipments and demand-related information, while concurrently scheduling outbound shipments. As a result, the warehouse or distribution manager is able to divert would-be double-handled inventory to satisfying an immediate customer requirement.

As turn-around-time decrease due to cross-docking capability, inventory levels decrease. The reason being is that warehouse and distribution process improvements enable inventory to flow uninterrupted through the distribution pipeline. Consequently, lead time reduction enables each supply chain member to carry fewer inventories. This is consistent with Little's Law, which states "the average number of customers in a stable system (over some time interval), N, is equal to their average arrival rate, λ, multiplied by their average time in the system, T, or $N = \lambda * T$."[54] Specifically, a decrease in cycle time translates to a decrease in total inventory.

D. CONCLUSION

In this chapter, the project group discussed how the DoD budget culture promotes excess inventory and discourages the implementation of better business practices, such as Lean Six Sigma. Particularly, the project group argued that since DoD is not-for-profit, there is no incentive for inventory managers to strive to reduce inventory; especially since budget managers are held accountable for not fully obligating budgeted funds. Moreover, throughout DoD there is a misconception that higher inventory levels translate to higher readiness. To counter this fallacy, the project group discussed the concept of operational availability. Operational availability defines the readiness of a weapon system as a measure of system uptime plus system downtime over the total time. Specifically, the readiness of the system is determined by either the reliability of the system or by maintenance and supply turn-around-time. In general, system reliability is a matter of system design. Consequently, investments into improving the system reliability are generally made during the early stages of the systems engineering process (i.e., system design, low rate initial production, operational testing, and etc.). Therefore, the focus of

[54] Wikipedia (2007b).

effort for maintenance and supply personnel should be on minimizing system downtime by improving both the efficiency of maintenance actions and the responsiveness of the supply chain.

Maintenance personnel can significantly improve maintenance turn-around-time by implementing better-business-practices such as Lean Six Sigma and ergonomics. Lean Six Sigma will enable maintenance personnel to identify and eliminate non-value added activities that translate to waste and impair the quality of maintenance actions. Moreover, Lean Six Sigma will enable maintenance personnel to statistically measure, analyze, and improve the efficiency of maintenance operations. To complement this, maintenance personnel can use ergonomics to reduce the flow of materials throughout maintenance facilities. Specifically, a reduction in the flow of materials translates to a reduction in process variation. Consequently, as process variation decreases, the quality of maintenance actions increases, which translates to less rework, faster turn-around-times, and higher operational availability.

Since the ability to perform maintenance depends heavily on the reliability of supply support, supply personnel must employ value-added activities that will improve the responsiveness of the supply chain and decrease Mean Supply Response Time (MSRT) or supply turn-around-time. Particularly, supply personnel should holistically implement value-added activities such as time-series forecasting, probabilistic inventory computation, prudent stockage criteria, information sharing, and efficient warehouse and distribution management. Collectively, these value-added activities will significantly improve supply turn-around-time and operational availability. Moreover, an improvement in supply turn-around-time translates to a reduction in inventory levels. The rationale for this is based upon the fact that safety stock is a factor of daily mean demand during lead time. Therefore, a lead time reduction translates to a safety stock reduction, which results in lower inventory expenses.

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V. CONCLUSION AND RECOMMENDATIONS

A. CONCLUSION

The goal of this project was to develop a consumable inventory management strategy for the Supply Management Unit (SMU) that will be applicable to other Department of Defense (DoD) supply support organizations. Specifically, the project group's goal was to provide the SMU with an appraisal of various methods of forecasting demand, probabilistic methods for computing inventory levels, methods for distinguishing feasible excess from returnable/disposable excess, and methods for determining the feasibility of stocking items. Moreover, the project group's objective was to provide the SMU with a holistic approach for decreasing Mean Supply Response Time (MSRT), which is a key driver in Operational Availability (Ao). This holistic approach would enable the SMU to significantly improve readiness, while simultaneously reducing needless inventory.

To accomplish this goal, the project group began by researching the current Marine Corps' orders and directives pertaining to forecasting, inventory management, and excess retention. Then, the project group contrasted this research to various operations management, supply chain management, and logistics engineering concepts. Next, the project group used the information gathered from these sources to analyze 24 months of historical demand data that was collected from a SMU. Specifically, the project group tested this data via various forecasting methods, probabilistic inventory computation methods, and inventory stockage criteria. Moreover, the project group tested the validity of the various inventory computational methods via an inventory management simulation. Lastly, the project group recorded the results from each assessment, which were used to prescribe an inventory management strategy for the SMU.

In analyzing the SMU's current process for forecasting demand, the project group found that the SMU unconventionally smoothes out demand fluctuations by eliminating high and low months of demand (high months are considered spikes). After removing high and low months of demand, the SMU calculates an arithmetic mean. Instead of using this arithmetic mean to conduct trend analysis and effectively measure forecast error, the SMU uses this forecast to compute inventory levels. This calculation is based upon the premise that demand is constant rather than variable. Consequently, the elimination of spikes from the computation of inventory levels often results in reorder points and safety levels that are too low. This translates to frequent stockouts and persistent backorders. Therefore, the project group recommended the implementation of various forecasting methods, such as moving average, weighted moving average, exponential smoothing, and exponential smoothing with trend.

The project group demonstrated how the SMU could use a moving average, weighted moving average, exponential smoothing, or exponential smoothing with trend to forecast demand and measure forecast error. Collectively, these methods would enable the SMU to conduct effective trend analysis, while accounting for demand variability. Moreover, the project group explained the importance of the SMU providing this demand-related information to the Defense Logistics Agency (DLA), General Services Administration (GSA), and other similar suppliers/distributors. By frequently providing demand-related information to suppliers, the SMU would be able to drastically reduce demand variability, which contributes to multiple layers of useless inventory throughout the supply chain. Essentially, as demand variability is reduced, each supply chain member's ability to forecast demand and establish inventory levels is optimized. This enhances the overall responsiveness of the supply chain, which translates to higher readiness and fewer inventories.

Besides demonstrating various forecast methods, the project group illustrated the various shortcomings of the Days of Supply model, which the SMU uses to compute inventory levels. In doing so, the project group explained how the SMU could effectively measure demand variability and calculate inventory levels based upon the probability of stockout. Depending upon the magnitude of demand variability, the project group prescribed the normal and Poisson distribution methods for computing inventory levels. Essentially, this will enable the SMU to use a probabilistic inventory method that accounts for demand variability rather than a deterministic inventory method that assumes that demand is constant.

To illustrate how probabilistic inventory methods will enable the SMU to significantly improve readiness, the project group tested newly computed inventory levels in an inventory simulation that incorporated demand and lead time variability. The simulation results demonstrated an improvement in item availability by up to 99.98 percent and a reduction in overall inventory value by up to 68.33 percent. Besides demonstrating an improvement in readiness and customer satisfaction, the simulated results indicated the potential for substantial inventory cost savings.

At face value, a 68.33 percent inventory reduction is extremely optimistic in that it excludes the computation of feasible excess. For that reason, project group prescribed a practical method for calculating excess retention quantities, which will enable the SMU to easily distinguish between feasible and returnable/disposable excess. This information will enable the SMU to gradually deplete its excess inventories, while minimizing the costs of reordering inventory. Based upon the project group's computations, approximately 28.99 percent of the SMU's inventory is returnable/disposable excess. Therefore, it can be inferred against the initial population that the SMU can potentially achieve an inventory savings of approximately $14.1 million. Moreover, as feasible excess depletes closer to the desired inventory level (i.e., the actual base stock level), an additional $11.1 million in inventory cost savings are expected.

Besides demonstrating different probabilistic inventory computational methods, the project group discussed various stockage criteria, which included the current Marine Corps' stockage criterion and the dollar-banding stockage criteria developed by the RAND Corporation. The project group discussed how the various dollar-banding stockage criteria (developed by the RAND Corporation) could enable the SMU to effectively reduce inventory levels. However, one drawback to this methodology is that item criticality is not considered in the inventory stockage decision. Instead, only demand frequency and cost are measured. Although demand frequency and cost are important considerations, item criticality must always be the foundation for stocking an item, especially since military readiness is the predominant factor. Therefore, the project group refurbished the current Marine Corps' stockage criterion by using item criticality, item attainability, item classification, and demand frequency, as the baseline for stocking an item, while incorporating dollar-banding cost methods into the prescription of service levels. Specifically, instead of using dollar-banding as an inventory stockage decision tool, dollar-banding was used to establish service levels for various items depending on criticality, demand frequency, and cost. Consequently, this stockage criterion will enable the SMU to focus on maximizing the availability of critical items, while efficiently balancing readiness with cost.

After discussing alternative stockage criteria, the project group discussed how the SMU could improve operational availability (or readiness) by reducing MSRT. Specifically, the project group discussed how to decrease MSRT via the integrated implementation of value-added activities, such as time-series forecasting, probabilistic inventory computation, information sharing, process management, and efficient warehouse and distribution management. As previously mentioned, sharing time-series demand forecasts and current inventory levels with suppliers decreases variability, which improves the overall responsiveness of the supply chain. Additionally, probabilistic inventory computational methods account for variability, while providing the flexibility of incorporating cost into the inventory stockage decision. Efficient process management via Lean Six Sigma will enable maintenance and supply personnel to identify and eliminate non-value added activities that create waste and impair the quality of maintenance and supply actions. Similarly, the implementation of efficient warehouse and distribution technologies and/or processes, such as cross-docking and In-transit visibility, also serve to reduce MSRT. Collectively, these value-added activities will significantly decrease MSRT and increase readiness, while simultaneously reducing redundant inventories throughout the supply chain.

In developing this strategy, the project group discussed the difficulties that a SMU would face in attempting to implement fundamental changes to the current standard operating procedures. DoD's budget culture alone presents a huge barrier to the effective implementation of an inventory reduction and cost savings strategy by the SMU. That being said, changes in the existing budget policies will have to be made before optimal results will be realized. For instance, the confines of the one-year Operations and Maintenance appropriation forces budget managers to obligate all requested funding by the end of each fiscal year. Despite the fact that cost savings results from improved efficiency, the inability to obligate all funding presents the risk of substantial budget cuts in the following year and excessive scrutiny of subsequent budget requests. In some instances, budget managers are held responsible for the inability to obligate funds, which endangers career progression. For that reason, spend-out waste continues to be a systemically endemic. Moreover, spend-out waste depletes funding that could be reallocated to various programs. This would enable program managers to invest into improving the system reliability of end items in the design phase, which results in substantial life cycle cost savings and improved readiness. Therefore, DoD needs to revamp its existing budget policies to offer incentives for improving readiness and reducing operational expenses (e.g., financial bonuses and career progression).

In conclusion, the implementation of better-business-practices at any level of DoD needs to be supported by leadership. That being said, leaders must be willing to accept honest feedback from subject matter experts with regards to the current condition of their organization. For instance, leaders must realize that performance metrics are designed to identify areas for improvement rather than just embellish areas that are already efficient. For that reason, leaders must develop and protect the integrity of metrics that accurately measure organizational performance. Lastly, leaders must acknowledge when change is needed and be willing to change. Otherwise, revolutionary initiatives that will improve readiness and reduce cost will stagnate.

B. SUGGESTIONS FOR FUTURE RESEARCH

This project focused solely on consumable inventory management. Nevertheless, concepts discussed in this project can be applied in other areas as well, such as repairable inventory management. Indeed, research into improving the availability of repairables via Lean Six Sigma would prove to be useful in improving operational availability. Also, concepts discussed in this project could be used to develop an inventory management strategy for a deployable unit (e.g., Marine Expeditionary Unit), which involves the construction of a repair parts block that is designed to maximize combat readiness during operational periods of demand. This research would prove useful as existing practices are outdated and generally ineffective.

APPENDIX A

A	**SERVICE/AGENCY REGULATED.** (Service/Agency use only.)* Issue, transfer, or shipment is controlled by authorities above the Inventory Control Point (ICP) level to assure proper and equitable distribution. 1. The use or stockage of the item requires release authority based on prior or concurrent justification. 2. Requisitions will be submitted in accordance with Service/Agency requisitioning procedures.
B	**ICP REGULATED.** (Service/Agency use only.)* Issue, transfer, or shipment is controlled by the ICP. 1. The use or stockage of the item requires release authority based on prior or concurrent justification. 2. Requisitions will be submitted in accordance with Service/Agency requisitioning procedures.
C	**SERVICE/AGENCY MANAGED.** (Service/Agency use only.)* Issue, transfer, or shipment is not subject to specialized controls other than those imposed by individual Service supply policy. 1. This item is centrally managed, stocked and issued. 2. Requisitions will be submitted in accordance with Service/Agency requisitioning procedures.
D	**DoD INTEGRATED MATERIEL-MANAGER (IMM) STOCKED, AND ISSUED.*** Issue, transfer, or shipment is not subject to specialized controls other than those imposed by the Integrated Materiel Manager/Military Service supply policy. 1. The item is centrally managed, stocked and issued. 2. Requisitions must contain the fund citation required to acquire the item. Requisitions will be submitted in accordance with Integrated Materiel-Manager/Military Service requisitioning procedures.
E	**OTHER SERVICE-MANAGED, STOCKED, AND ISSUED.** (For Service use only if SICA LOA is 8D and NIMSC is 6.) Issue, transfer, or shipment is not subject to specialized controls other than those imposed by the Service requisitioning policy. 1. The item is centrally managed, stocked and issued. 2. Requisitions may require a fund citation and will be submitted in accordance with the Service requisitioning procedures.
F	**FABRICATE OR ASSEMBLE* NONSTOCKED ITEMS.** National Stock Numbered items fabricated or assembled from raw materials and finished products as the normal method of support. Procurement and stockage of the items are not justified because of low usage or peculiar installation factors. Distinctions between local or centralized fabricate/assembly capability are identified by the Source of Supply Modifier in the Source of Supply Column of the Service Management Data Lists.
G	**GENERAL SERVICES ADMINISTRATION (GSA) CIVIL AGENCY INTEGRATED MATERIEL MANAGED, STOCKED, AND ISSUED.** Identifies GSA/Civil Agency-managed items available from GSA/Civil Agency supply distribution facilities. Requisitions and fund citations will be submitted in accordance with GSA/Civil Agency/Service requisitioning procedures.
H	**DIRECT DELIVERY UNDER A CENTRAL CONTRACT* (NON-STOCKED ITEMS).** Issue, transfer, or shipment is not subject to specialized controls other than those imposed by IMM/Service/Agency supply policy. 1. The item is centrally managed and procured. 2. Normal issue is by direct shipment from the vendor to the user at the order of the ICP or IMM. However, orders for quantities less than the vendor's minimum order quantity may be issued from stock by ICP or IMM supply distribution facilities. 3. Requisitions and fund citations will be submitted in accordance with IMM/Service/Agency requisition procedures. 4. Generally delivery will be made within applicable Service/Agency guidelines addressing customer required timeframe.
I	**DIRECT ORDERING FROM A CENTRAL CONTRACT/SCHEDULE NONSTOCKED ITEMS.** Issue, transfer, or shipment is not subject to specialized controls other than those imposed by Integrated Materiel-Manager/Service supply policy. The item is covered by a centrally issued contractual document, or by a multiple award Federal supply schedule, which permits using activities to place orders directly on vendors for direct delivery to the user.
J	**NOT STOCKED, CENTRALLY PROCURED NONSTOCKED ITEMS.** IMM/Service centrally

	managed but not stocked item. Procurement will be initiated only after receipt of a requisition.
K	**CENTRALLY STOCKED FOR OVERSEAS ONLY*** Main means of supply is local purchase or direct ordering from a central contract/schedule when the Federal Supply Schedule Number is shown in the CMD record. Item is stocked in domestic supply system for those activities unable to procure locally due to nonavailability of procurement sources or where local purchase is prohibited (e.g., ASPR; Flow of Gold or by internal Service/Agency restraints). Requisitions will be submitted by overseas activities in accordance with Service/Agency requisitioning procedures. NOTE: Continental U.S. (CONUS) activities will obtain supply support through local procurement procedures.
L	**LOCAL PURCHASE NONSTOCKED ITEMS.*** DLA/GSA/Service/Agency managed items authorized for local purchase as a normal means of support at base, post, camp or station level. Item not stocked in wholesale distribution system of Integrated Materiel-Manager/Service/Agency Inventory Control Point.
M	**RESTRICTED REQUISITIONS - MAJOR OVERHAUL*** (Service/Agency use only.) Items (assemblies and/or component parts) which for lack of specialized tools, test equipment, etc., can be used only by major overhaul activities. Base, post, camp, or station activities will not requisition unless authorized to perform major overhaul function.
N	**RESTRICTED REQUISITIONING - DISPOSAL.** (Service/Agency use only.)* Discontinued items no longer authorized for issue except on the specific approval of the Service inventory manager. Requisitions may be submitted in accordance with Service requisitioning procedures in instances where valid requirements exist and replacing item data has not been furnished.
O	**PACKAGED FUELS NONSTOCKED ITEMS.** DLA-managed and Service- regulated. 1. Item will be centrally procured in accordance with DoD 4140.25-M, Procedures for the Management of Petroleum Products, but not stocked by IMM. Long lead time required. 2. Requirements will be satisfied by direct shipment to the user either from a vendor or from Service assets at the order of the ICP or IMM. 3. Requirements and/or requisitions will be submitted in accordance with Service procedures.
P	**RESTRICTED REQUISITION - SECURITY ASSISTANCE PROGRAM (SAP).** 1. Indicates item is stocked or acquired only for SAP (replaces Military Assistance Program (MAP)) requirements, or 2. Indicates item is nonstocked and materiel is ordered from the contractor for shipment directly to the foreign government. 3. Base, post, camp or stations will not requisition.
Q	**BULK PETROLEUM PRODUCTS.** DLA-managed. 1. Item may be either centrally stocked or available by direct delivery under a central contract. 2. Requirements will be submitted by Military Services in accordance with IMM procedures. 3. Item will be supplied in accordance with DoD 4140.25-M.
R	**RESTRICTED REQUISITION - GOVERNMENT FURNISHED MATERIEL (GFM).** Indicates item is centrally procured and stocked as GFM in connection with the manufacture of military items. Base, post, camp or stations will not requisition.
S	**RESTRICTED REQUISITIONING - OTHER SERVICE FUNDED.** (Service use only.) For Service-managed items whereby the issue, transfer, or shipment is subject to specialized controls of funding Military Service. 1. Item is procured by a Military Service for the funding Military Service and is centrally managed by the funding Military Service. 2. The procuring Military Service has no requirement in its logistics system for the item.
T	**CONDEMNED NONSTOCKED ITEM.** Item is no longer authorized for procurement, issue, use or requisitioning.
U	**LEAD SERVICE-MANAGED.** As a minimum provides procurement, disposal, and single submitter functions. Wholesale logistics responsibilities which are to be performed by the PICA in support of SICA are defined by the SICA NIMSC code.
V	**TERMINAL ITEM.*** Identifies items in stock, but future procurement is not authorized. Requisitions may continue to be submitted until stocks are exhausted. Preferred item National Stock Number (NSN) is normally provided by the application of the phrase: "When Exhausted Use (NSN)." Requisitions will be submitted in accordance with IMM/Service requisitioning procedures as applicable.
W	**RESTRICTED REQUISITIONING - SPECIAL INSTRUCTIONS APPLY NONSTOCKED ITEM.** Indicates stock number has been assigned to a generic item for use in bid invitations, allowance lists, etc., against which no stocks are ever recorded. Requisitions will be submitted only in accordance with IMM/Service requisitioning procedures. (This code will be used, when

	applicable, in conjunction with Phrase Code S (Stock as NSN(s). It is considered applicable for use when a procurement source(s) becomes available. The Phrase Code S and the applicable "stock as" NSN(s) will then be applied for use in stock, store and issue actions.)
X	**SEMIACTIVE ITEM - NO REPLACEMENT NONSTOCKED ITEM.** A potentially inactive NSN which must be retained in the supply system as an item of supply because (1) stocks of the item are on hand or in use below the wholesale level and (2) the NSN is cited in equipment authorization documents TO&E, TA, TM, etc., or in-use assets are being reported. 1. Items are authorized for central procurement but not authorized for stockage at wholesale level. 2. Requisitions for in-use replacement will be authorized in accordance with individual Military Service directives. 3. Requisitions may be submitted as requirements generate. Repetitive demands may dictate an AAC change to permit wholesale stockage.
Y	**TERMINAL ITEM* (NONSTOCKED ITEMS).** Further procurement is not authorized. No wholesale stock is available for issue. 1. Requisitions will not be processed to the wholesale manager. 2. Internal Service/Agency requisitioning may be continued in accordance with Service/Agency requisitioning policies.
Z	**INSURANCE/NUMERIC STOCKAGE OBJECTIVE ITEM.*** Items which may be required occasionally or intermittently and prudence requires that a normal quantity of materiel be stocked due to the essentiality or the lead time of the item. 1. The item is centrally managed, stocked, and issued. 2. Requisitions will be submitted in accordance with IMM/Service requisitioning procedures.

Table 15. Acquisition Advice Codes (from: DLA Customer Assistance Hand Book)

* Authorized for segment B input.

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APPENDIX B

Code	Description
A	End Item
B	Consumable Repair Parts (Recoverability Code C or Z)
C	Type II As Required Items
D	Dry Cell Batteries
E	Modification Kits
F	Field Fortification Material
G	General Articles, Type III
H	Petroleum, Oils and Lubricants
I	Individual Clothing
J	Cold Weather Clothing and Equipment
K	Reserved
L	Lumber
M	Medical Equipment & Supplies (Class VIII)
N	Special Managed Items
O	Ancillary Items/SL-3 Components
P	Artic Materiel
Q	Supply System Responsibility Items (SSRI) & Collateral Material
R	Combat Rations
S	Maintenance Float Secondary Depot Reparable (Recoverability Code D or L)
T	Maintenance Float Secondary Non-Depot Reparable (Recoverability Code O, F, or H)
U	Organizational Clothing and Individual Equipment
V	Chemical Warfare Items
W	Preservation, Packaging, and Packing Materiel
X	Reserved
Y	Jungle Items
Z	Desert Materiel

Table 16. Materiel Identification Codes (from: UM-4400-124)

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APPENDIX C

Code	Description
0	Non-combat Essential End Item
1	Combat Essential End Item
2	Non-critical Repair Part
3	Critical Item/Repair Part Health and Safety of Personnel
4	Critical Item/Repair Part for State and Local Laws
5	Critical Repair Part to a Combat Essential End Item
6	Critical Repair Part to a Non-Combat Essential End Item

Table 17. Combat Essentiality Codes (from: UM-4400-124)

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APPENDIX D

Code	Description
A	Item requires special handling. (e.g., Batteries)
D	Repairable Item. (Depot Level)
F	Repairable Item. (Intermediate Level)
H	Repairable Item. (Intermediate Level)
L	Repairable Item. (Depot Level)
O	Repairable Item. (Intermediate Level)
Z	Non-reparable item.

Table 18. Recoverability Codes (from: UM-4400-124)

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LIST OF REFERENCES

GOVERNMENT DOCUMENTS

GAO Report (1997) *DoD's High Risk Areas: Eliminating Underlying Causes Will Avoid Billions of Dollars in Waste,* GAO/T-NSIAD/AIMD-97-143.

GAO Report (2007) *DoD's High Risk Areas: Efforts to Improve Supply Chain Can Be Enhanced by Linkage to Outcomes, Progress in Transforming Business Operations, and Reexamination of Logistics Governance and Strategy,* GAO-07-1064T.

Marine Corps Users Manual (1984) *FMF SASSY Using Unit Procedures,* UM-4400-124.

Marine Corps Order (1992) *Intermediate-level Supply Policy Manual,* MCO P4400-151B.

Office of the Chief of Naval Operations Instruction Manual (2003) *Operational Availability,* OPNAVINST3000.12A.

Standard Operating Procedures (2007) *Supply Management Unit Stock Control Procedures.*

RESEARCH

Apte, U., Aquilano, N. J., Jacobs, R., Cohen, M. A., Chase, R. B., Shroeder, R. G., Fitzsimmons, J. A., and Fitzsimmons, M. J. (2006) *Operations Management,* McGraw-Hill/Irwin.

Balakrishnan, N., Render, B., and Stair, R. M. (2007) *Managerial Decision Modeling with Spreadsheets,* Prentice Hall.

Ferrer, G. (2007a) *Operations Management: Supply Chain Management,* McGraw-Hill/Irwin.

Fricker, R. D. and Robbins, M. (2000) *Retooling for the Logistics Revolution: Designing Marine Corps Inventories to Support the Warfighter*, RAND Corporation.

Keller, G. (2007) *Statistics for Management and Economics,* Thomson Brooks/Cole.

McCaffery, J. L., & Jones, L.R., (2006) *Budgeting and Financial Management for National Defense,* Information Age Publishing.

ARTICLES

Kang, K. (1998) "DoD Inventory Management Cultural Changes and Training in Commercial Practices," Naval Postgraduate School Report: NPS-SM-98-002.

Kozar, M.J. (1993) "An Analysis of Obligation Patterns for the Department of Defense Operations and Maintenance Appropriations," Naval Postgraduate School Masters Thesis: K834775.

PRESENTATIONS

Doerr, K. (2007) "Inventory," GB3042 (Operations Management), Lecture Notes, Naval Postgraduate School.

Ferrer, G. (2007b) "Demand Management," GB3420 (Supply Chain Management), Lecture Notes, Naval Postgraduate School.

INTERNET SITES

ORMS Today (2007) "Part Tool Part Process: Inventory Optimization at Hewlett Packard," http://www.lionhrtpub.com/orms/orms-10-99/cargille.html. Last accessed 8 August 2007.

Rollins College (2007) "Bullwhip Effect," http://web.rollins.edu/~tlairson/ecom/Image4.gif. Last accessed 13 August 2007.

Wikipedia (2007a) "Electronic Data Interchange," http://en.wikipedia.org/wiki/Electronic_Data_Interchange. Last accessed 4 October 2007.

Wikipedia (2007b) "Little's Law," http://en.wikipedia.org/wiki/Little's_law. Last accessed 4 October 2007.

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